

The State of Water Quality in Wilmington:

One of the City's Most Valuable Resources



A State of the Environment Report

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Development Services, Planning Division
Environmental Planning

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1. Introduction to Wilmington's Watersheds

An area of land that drains into a particular water body is known as a watershed (Doll & Spence, 1997). Wilmington is located at the meeting of two major watersheds, the Cape Fear River and the Atlantic Intracoastal Waterway. All surface waters in Wilmington drain to one of these two water bodies and are divided into two groups: tidal creeks and Cape Fear River tributaries. Tidal creeks drain directly into the Atlantic Intracoastal Waterway and make up the eastern portion of Wilmington's surface waters. Cape Fear River tributaries drain directly to the Cape Fear River and comprise the western portion of Wilmington's surface waters.

Figure 1.1 Wilmington's Creeks

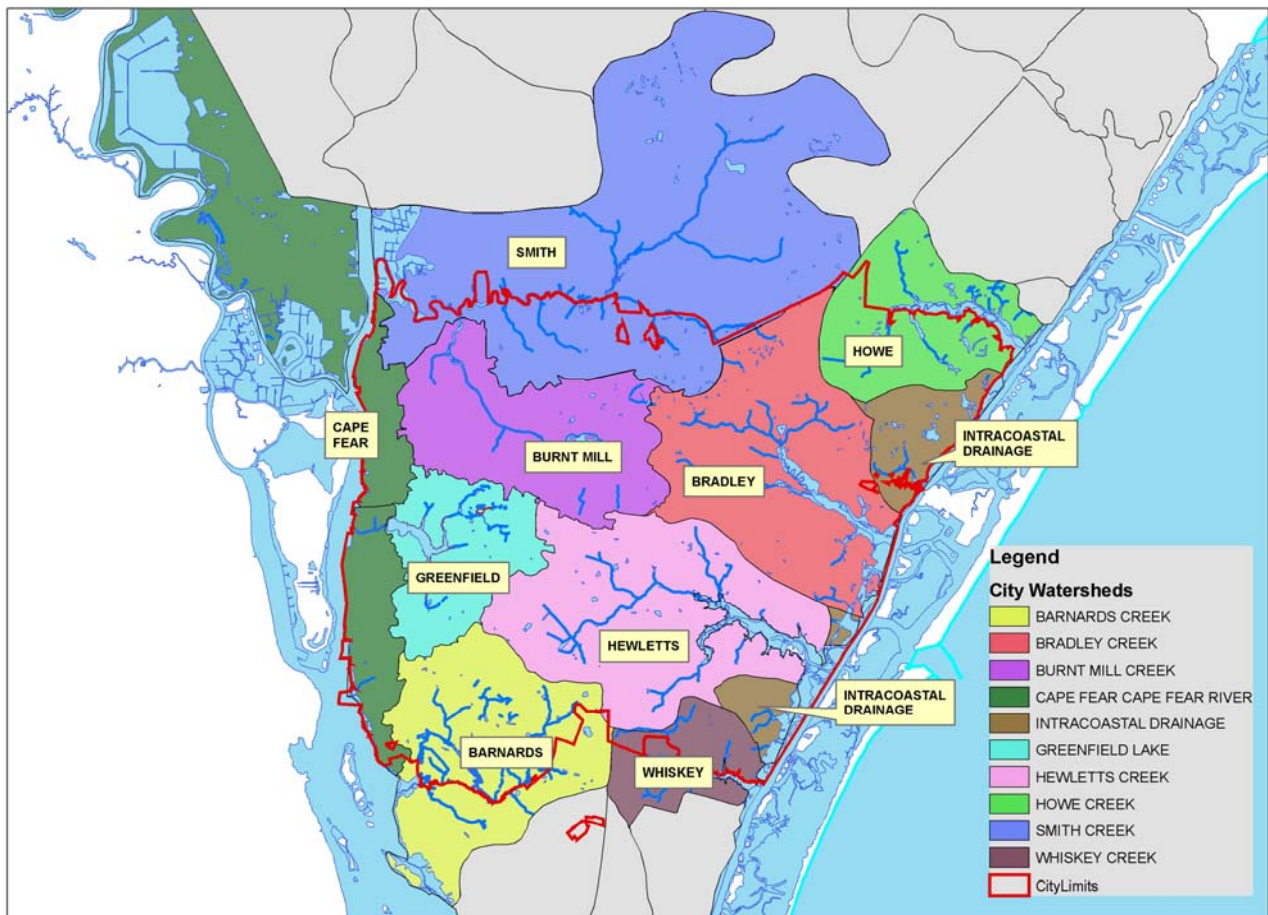
Tidal Creeks

Bradley Creek
Hewlett's Creek
Howe Creek
Whiskey Creek

Tributaries

Barnard's Creek
Burnt Mill Creek
Greenfield Creek
Smith Creek

Watersheds in Wilmington



2. Regulation

One of the intentions of the Clean Water Act, the major piece of legislation dealing with surface waters, is “to restore and maintain the chemical, physical and biological integrity of the Nation’s waters” (Sec. 1251(a)). The Environmental Protection Agency (EPA) is the federal agency responsible for carrying out this directive. The Clean Water Act established water quality standards and a permitting system, the National Pollutant Discharge Elimination System (NPDES), to protect water quality (Doll & Spence, 1997). Each state is required to meet the water quality standards in the Clean Water Act, as well as other standards and regulations developed by the EPA, through state-level, EPA-approved programs. The North Carolina Department of Environment and Natural Resources (NCDENR) is the state agency in charge of ensuring that EPA standards are met. Clean Water Act and EPA standards are considered the minimum, and states may choose to implement stricter or more comprehensive regulations.

Figure 2.1 Regulation Hierarchy



The first step in regulation is to define the best uses to be protected within a water body. North Carolina has adopted a classification system, based on one developed by the EPA, to determine the best uses for each surface water body. The Division of Water Quality assigns classifications, under the authority of NCDENR’s Environmental Management Commission, and enforces the classification system. The Tidal Saltwater Classification System contains three primary classifications and the Surface Freshwater Classification System consists of seven primary classifications (NCDENR, 2003a). Every surface water body in North Carolina receives a primary classification and may also receive one of five supplemental classifications or an additional classification from other divisions or agencies (NCDENR, 2001a, 2001b). All waters in North Carolina must at least meet Class C standards (fishable/ swimmable). All other classifications provide additional levels of protected uses. See Appendix A for a current-state summary of Wilmington’s waters and Appendix B for information on classifications other than those applied to waters in Wilmington.

Tidal Saltwater Primary Classifications Used in Wilmington

SC: Saltwater Class C. Aquatic life propagation and maintenance of biological integrity (including fishing, fish, and functioning primary nursery areas (PNA's)), wildlife, secondary recreation (including recreational fishing, boating, and water related activities involving minimal skin contact), and any other usage except primary recreation or shellfishing for market purposes (NCDENR, 2003a).

SA: Saltwater Class A. Shellfishing for market purposes and any other usage specified for SB or SC waters. All SA waters are also High Quality Waters (HQW) (NCDENR, 2003a).

Surface Freshwater Primary Classifications Used in Wilmington

C: Waters protected for secondary recreation, fishing, wildlife, fish and aquatic life propagation and survival, agriculture and other uses suitable for Class C. There are no restrictions on watershed development or types of use (NCDENR, 2001b).

Supplemental Classifications Used in Wilmington

HQW: High Quality Waters. Waters which are rated excellent based on biological and physical/chemical characteristics through Division monitoring or special studies, native and special native trout waters (and tributaries) designated by the Wildlife Resources Commission, primary nursery areas (PNA's) designated by the Marine Fisheries Commission, and other functional nursery areas designated by the Marine Fisheries Commission (NCDENR, 2003a).

ORW: Outstanding Resource Waters. Unique and special surface waters of the state that are of exceptional state or national recreational or ecological significance that require special protection to maintain existing uses (NCDENR, 2003a).

SW: Swamp Waters. Waters which are topographically located so as to generally have very low velocities and other characteristics different from adjacent streams draining to steeper topography (NCDENR, 2003a).

Each classification has specific associated numeric and narrative standards used to determine whether or not the uses designated for a water body are being protected (see Appendix B for associated standards). Once a water body has been classified, the state is required by the EPA to maintain the water at that level of quality. Section 303(d) of the Clean Water Act requires states to submit a list every two years (The North Carolina Impaired Waters List) of waters that are not meeting designated standards or uses or are in danger of degrading to a lower classification. The state must prioritize the impaired waters and develop a management strategy, or Total Maximum Daily Load (TMDL), to address the cause of impairment and improve the water quality (NCDENR, 2003a). To prioritize impaired waters, North Carolina has adopted a seven-category assessment system. Categories 4, 5, 6, and 7 constitute the Impaired Waters List, also sometimes referred to as the North Carolina 303(d) list which together with the 305(b) report of water quality assessment is referred to as the Combined Report. Currently, seven of Wilmington's nine water bodies are on the Impaired Waters List (NCDENR, 2003a).

North Carolina Water Quality Assessment Categories

Categories 1, 2, and 3: Waters that are either fully or partially supporting their designated uses. These waters are not listed on the Impaired Waters List (NCDENR, 2003a).

Category 4: Waters that are impaired or threatened but are not yet so impaired as to require the development of a TMDL. Category 4 is divided into categories 4a, 4b, and 4c (NCDENR, 2003a).

Category 5: Waters that have been impaired by one or more pollutants. A TMDL is required for all listed pollutants (NCDENR, 2003a).

Category 6: Waters that have been impaired based on biological data. A TMDL is generally required, though in some cases there may not be available data to develop a TMDL (NCDENR, 2003a).

Category 7: Waters that are impaired by causes for which proper technical conditions to develop a feasible TMDL do not exist (NCDENR, 2003a).

3. Monitoring and Management

Point Sources

To help manage what goes into surface waters in the U.S., the EPA established the National Pollutant Discharge Elimination System (NPDES). NPDES is a permitting system for point sources that discharge into surface waters. In North Carolina, the system is administered through the NPDES Unit of the Point Source Branch of NCDENR's Division of Water Quality, Water Quality Section. The NPDES Unit is responsible for reviewing and either approving or denying permit applications. The NPDES Unit determines the quality and quantity of wastewater discharges a stream may assimilate. Permits for point sources are designed to include flow, pollutant, and toxicant limitation levels. The permitting process is coordinated with the basinwide planning process, with permits issued and renewed concurrently every five years (NCDENR 2004).

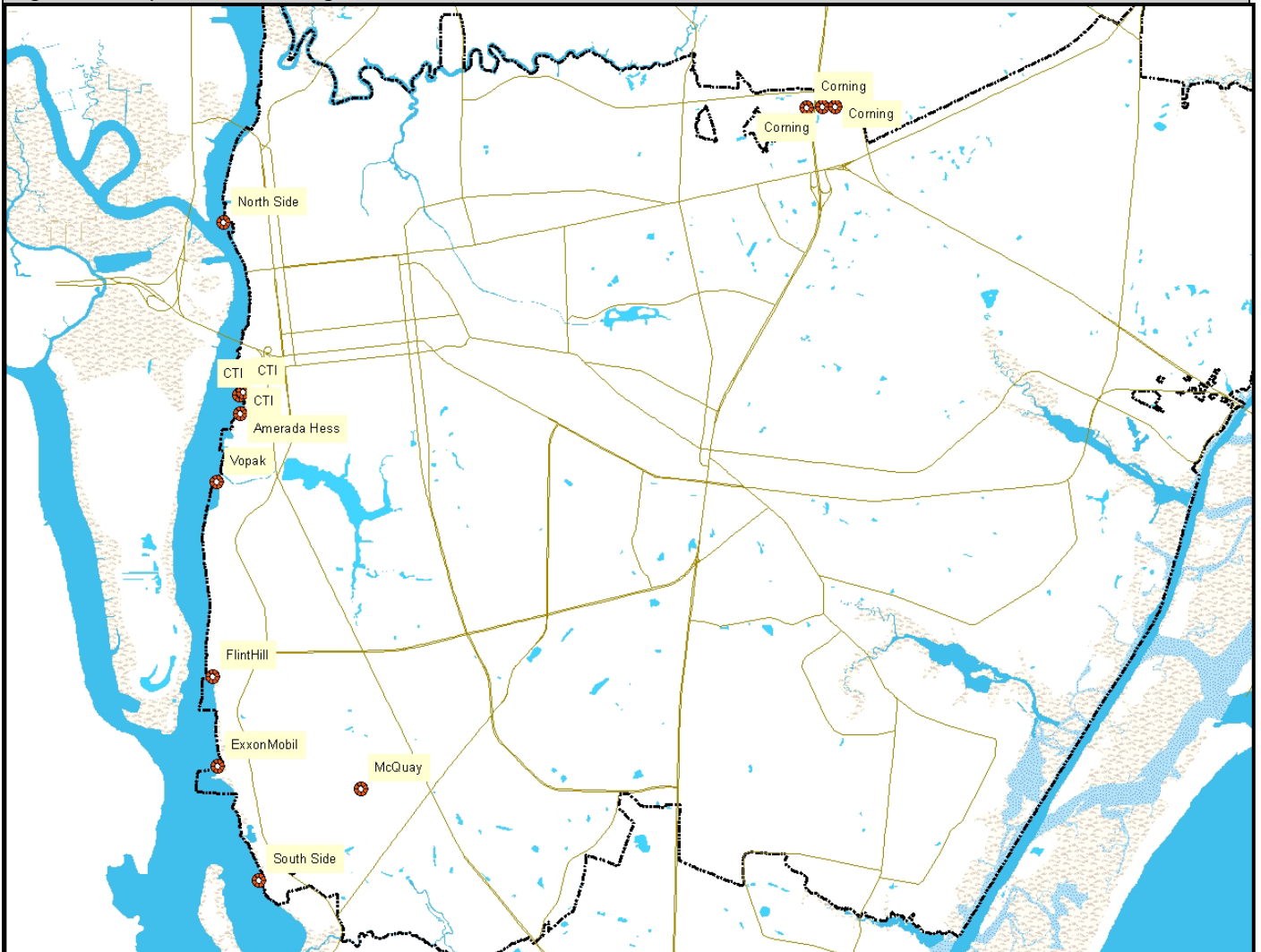
There are two types of permits: general and individual. General permits are developed for specific industry classifications statewide, with discharge permit parameters set according to the type of industry. General permits are issued to facilities engaged in specific industrial activities that are considered typical within a specified classification. Because general permits are developed per industry and not per facility, general permits do not take specific watersheds into consideration. Individual permits are issued to facilities engaged in activities considered to be atypical or to those with a history of water quality problems (NCDENR 2004).

The NPDES Unit is also responsible for enforcing compliance with permit limitations. Dischargers are required to self-monitor discharge levels and submit a discharge monitoring report (DMR) to DWQ each month. DWQ staff also performs routine site inspections. Fines for permit noncompliance violations vary. (NCDENR, *NPDES: History*). The maximum fine for discharging without a permit is \$10,000 per day. There are currently 10 active NPDES discharge permits in Wilmington.

Table 3.1 National Pollutant Discharge Elimination System (NPDES) Permits

Permitted Facility	Discharge	Effluent Limits			Additional Monitoring (no specified limits)	Receiving Waters
AAF-McQuay, Inc. #NC0083658	Treated groundwater	Trichloroethene daily max.: 81 µg/L 1,1-Dichloroethene daily max.: 3.2 µg/L Total Suspended Solids daily max.: 30 mg/L Flow.: 0.36 MGD monthly average pH: between 6 and 9 standard units			EPA Method 601 EPA Method 625	Barnard's Creek
Amerada Hess Corp. #NC0066711	Storm water, boiler blowdown water, truck and loading rack waters, hydrostatic test waters, floor cleaning waters	Total Suspended Solids daily max.: 45 mg/L			Flow Oil and grease MTBE Benzene Xylene Toluene Ethylbenzene EPA Method 625 Acute toxicity	Cape Fear River
Corning Inc. #NC0003794	Cooling water	pH: between 6 and 9 standard units			Flow Temperature Total residue solids	Smith Creek
CTI #NC0082970	Treated storm water	Total Suspended Solids daily max.: 45 mg/L			Flow Oil and grease Benzene Ethylbenzene Toluene Xylene EPA Method 624/625	Cape Fear River
Flint Hill Resources #NC0076732	Storm water, tank bottom water, hydrostatic test water, groundwater	Flow: 0.1 MGD monthly average Total Suspended Solids daily max.: 45 mg/L			Oil and grease MTBE Xylene Iron Manganese EPA Methods 624/625 Acute toxicity	Cape Fear River
International Paper #NC0081507	Not specified	Flow: 0.025 MGD monthly average Oil and grease daily max.: 30 mg/L Toluene daily max: 48 µg/L			Chronic toxicity Volatiles (EPA Method 625) Acetone MEK	Burnt Mill Creek
JLM Terminals #NC0028568	Storm water	Total Suspended Solids daily max.: 45 mg/L			Flow Oil and grease Benzene Naphthalene Xylene EPA Method 8015 Acute Toxicity	Cape Fear River
Northside WWTP #NC0023965	Treated waste water		Monthly Average	Weekly Average	NH ₃ , Nitrogen Phosphorous Residual Chlorine Temperature Acute Toxicity Copper, Cyanide Mercury, Silver Dissolved Oxygen	Cape Fear River
		Flow BOD F. coliform	8.0 MGD 30 mg/L 200/100 mL	45 mg/L 400/100mL		
Paktank/ Vopak Terminal #NC0073172	Boiler blowdown, storm water	Total Suspended Residue daily max.: 45 mg/L			Flow Xylene Acute toxicity Methanol EPA Methods 624/625	Cape Fear River
Southside WWTP #NC0023973	Treated waste water		Monthly Average	Weekly Average	NH ₃ , Nitrogen Phosphorous Residual Chlorine Temperature Acute Toxicity Dissolved Oxygen Copper, Cyanide	Cape Fear River
		Flow BOD Suspended Residue F. coliform	12 MGD 30 mg/L 30 mg/L 200/100 mL	45 mg/L 45 mg/L 400/100 mL		

Figure 3.1: Map of NPDES Discharge Locations



Nonpoint Sources

Nonpoint sources are the largest contributors of water quality degrading pollutants. Unlike point source discharges, where substances enter surface waters from discrete, identifiable, and easily monitored sources, nonpoint sources contribute substances to surface and ground waters through less obvious means and diffuse sources, such as infiltration and storm water surface runoff.

Table 3.2. Urban Nonpoint Pollutants		
Category	Parameters	Potential Sources
Bacteria	Total and fecal coliforms, fecal streptococci, other pathogens	Animals, birds, soil bacteria, humans
Nutrients	Nitrogen and phosphorous	Pets, birds, animals; lawn fertilizers; decomposing organic matter (leaves and grass clippings); urban street refuse, atmospheric deposition
Biodegradable chemicals	Biological oxygen demanding wastes, chemical oxygen demanding wastes, total organic carbon	Leaves, grass clippings, animals, street litter, oil and grease
Organic chemicals	Pesticides, PCBs	Pest and weed control, packaging, leaking transformers, hydraulic and lubricating fluids
Inorganic chemicals	Suspended solids, dissolved solids, toxic metals, chloride	Erosion (lawns, stream banks and channels, construction sites), dust and dirt on streets, atmospheric deposition, industrial pollution, illegal dumping during storms, traffic
Physical and aesthetic	Thermal, discoloration, odors	Heated streets, parking lots, sidewalks, and rooftops (summer only), runoff from industrial sites, animal wastes and organic matter, hydrocarbons
<p>Source: Barnes et al. (2001). Adapted from:</p> <p>Novotny, V. & Chesters, G. (1981). <i>Handbook of urban nonpoint pollution: Sources and management</i>. New York: Van Nostrand Reinhold Company.</p> <p>Hansen, N.R., Babcock, H.M., & Clark II, E.H. (1988). <i>Controlling Nonpoint-source water pollution: A citizen's handbook</i>. Washington D.C.: The Conservation Foundation and the National Audubon Society.</p> <p>Whipple Jr., W. (1977). <i>Planning of water quality systems</i>. Lexington, MA: Lexington Books.</p>		

While in some cases pollutants enter waterways directly from the pollutant source, like bacteria infiltrating from malfunctioning septic systems or sediment eroding from a construction site adjacent to a waterway, most nonpoint pollutants enter waterways in storm water runoff from impervious surfaces, such as rooftops, roads, sidewalks, parking lots, and compacted soils. When an area is developed with impervious surfaces rainwater is prevented from absorbing into the soil and dispersing slowly and naturally. As a result, a large volume of water accumulates and flows rapidly over the impervious surfaces into waterways. This excess water, known as storm water runoff, washes the physical, chemical, and biological pollutants listed above into streams and creeks (Doll & Spence).

Sediment

Storm water pollutants degrade water quality in a variety of ways. Sediments, argued by Barnes et al. (2001) to be the greatest hazard to aquatic organisms in urban watersheds, cause physical water quality degradation. Sediments washed from impervious surfaces into waterways increase turbidity, the amount of suspended particles in the water column (Barnes et al.). Increased turbidity can be fatal for submerged aquatic plants by preventing infiltration of the sunlight necessary for photosynthesis (Doll & Spence, 1997). Loss of aquatic plants means loss of habitat for juvenile fish and other aquatic organisms, thus reducing the stability of nursery areas and fish stocks. Turbidity can also be fatal for fish and filter-feeding animals, like shellfish, whose gills and feeding mechanisms can become clogged by the particles, preventing feeding and/or breathing (Doll & Spence). Sediments further physically disrupt the aquatic food web by scouring plant materials from rocks, depriving grazing aquatic animals of their food source (Barnes et al.).

Another physical impact of sediments is sedimentation, the deposition of particles onto the stream bed. Sedimentation smothers fish eggs, aquatic plants, and the larva and juveniles of various aquatic organisms (Barnes et al., 2001), and disrupts the riffle/pool sequence (natural alternating pattern of shallow fast moving water followed by deeper, slower moving pools) important to habitat for many organisms. Sedimentation also causes waterways to become shallower, reducing aquatic habitat and increasing future flood risk (City of Wilmington, n.d.), increases abrasiveness of the stream current resulting in a more erosive stream flow. Other water pollutants can attach to sediment particles and be washed with the sediment into waterways (Barnes et al. and Doll & Spence, 1997). These pollutants are then released or settle to the bottom to be churned up again with the next storm water influx.

Nutrients

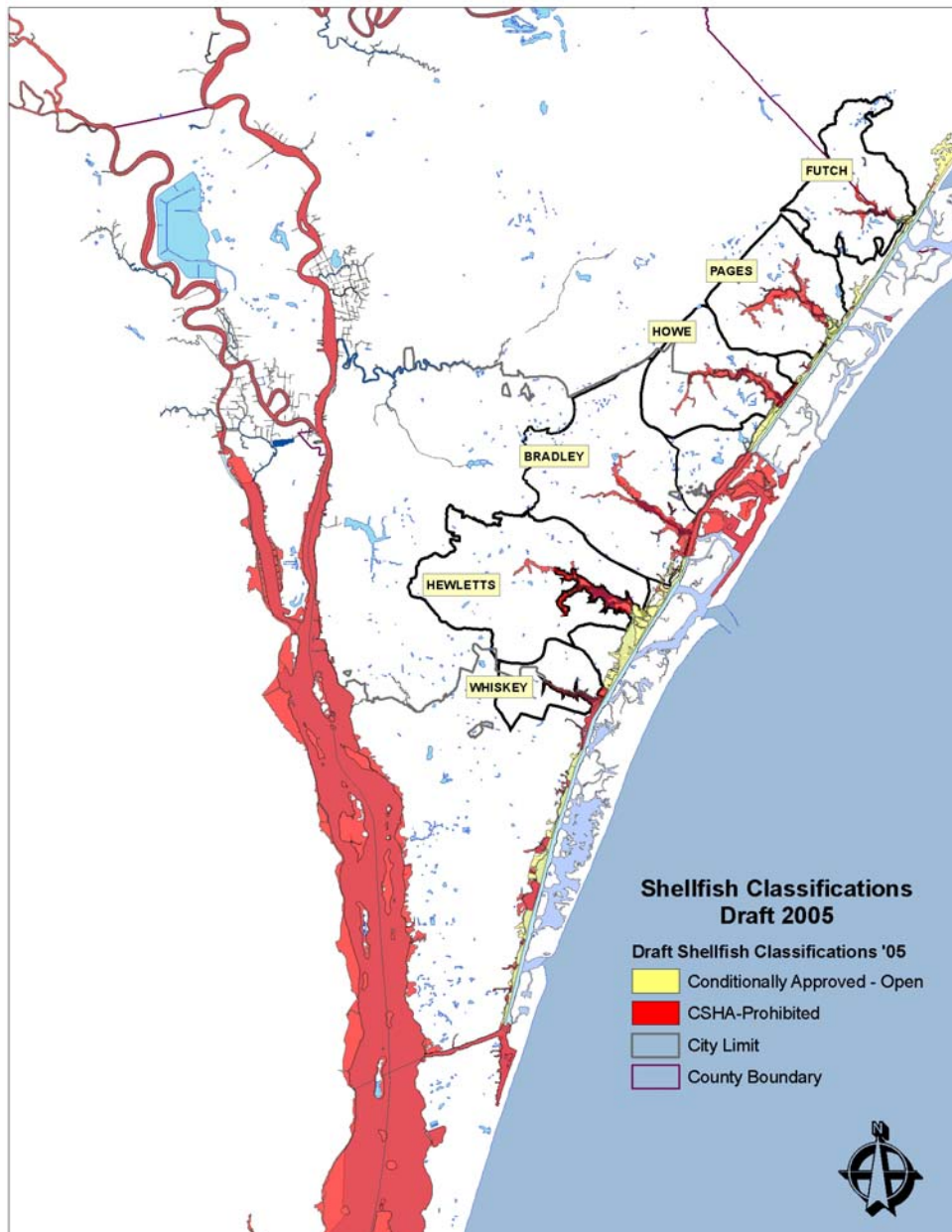
Nutrients, mainly nitrogen and phosphorous, are naturally occurring chemical components of aquatic systems, enabling the growth and reproduction of aquatic plants and algae (Doll & Spence, 1997). Nutrients are also present, however, in detergents, fertilizers, and human and animal waste (Jolley, n.d.). Nutrient pollution occurs when excess nutrients from human and animal sources are washed into waterways, causing excessive plant and algae growth. When plants and algae become too prevalent in an aquatic system, a condition known as eutrophication, fish and other aquatic organisms can be suffocated through lack of dissolved oxygen in the water (Doll & Spence). Greenfield Lake experiences eutrophic conditions regularly.

Pathogens

Bacteria and viruses are two more pollutants that are washed into waterways by storm water runoff. Unlike eutrophication, biological pollutants, such as the pathogens that cause viral hepatitis, infectious cholera, and gastroenteritis, present a direct human health hazard (Doll & Spence, 1997). These pathogens contaminate shellfish and can cause serious illness in people who eat the contaminated organisms. In addition, Mallin, Cahoon, Posey, Johnson, Alphin, Parsons, et al. (2004) of the UNCW Center for Marine Science Research found that bodily contact with sediments contaminated by such pathogens “would likely be particularly hazardous,” and that disturbance of these sediments “can add a significant health threat to certain water bodies.” Fecal coliform bacteria, found in human and animal waste, is used as an indicator of the likely presence of harmful human pathogens. High fecal coliform levels have resulted in the closing of large portions of previously productive shellfish areas in each of

Wilmington's tidal creeks and the Cape Fear River (Figure 3.3). High fecal coliform levels have been shown to correspond to increasing impervious surface coverage.

Figure 3.2: Shellfish Closure Areas - 2005



Toxic Substances

Storm water runoff carries other toxic substances to waterways, as well. Metals and chemicals that are found in pesticides, paints, lawn chemicals, gasoline, oil, and other substances are often spilled or leaked onto the ground. These substances are pollutants of serious concern, as they do not biodegrade and can be toxic to aquatic life at relatively low concentrations (Doll & Spence, 1997). Low levels of such toxins can cause reproductive disorders, tumors, and other chronic effects. High doses can be lethal (Doll & Spence). These pollutants are also of particular concern with regard to human health, as they can build up in fish and shellfish tissues and become more and more concentrated up the food chain, ultimately causing toxicity in humans who eat affected organisms (Doll & Spence).

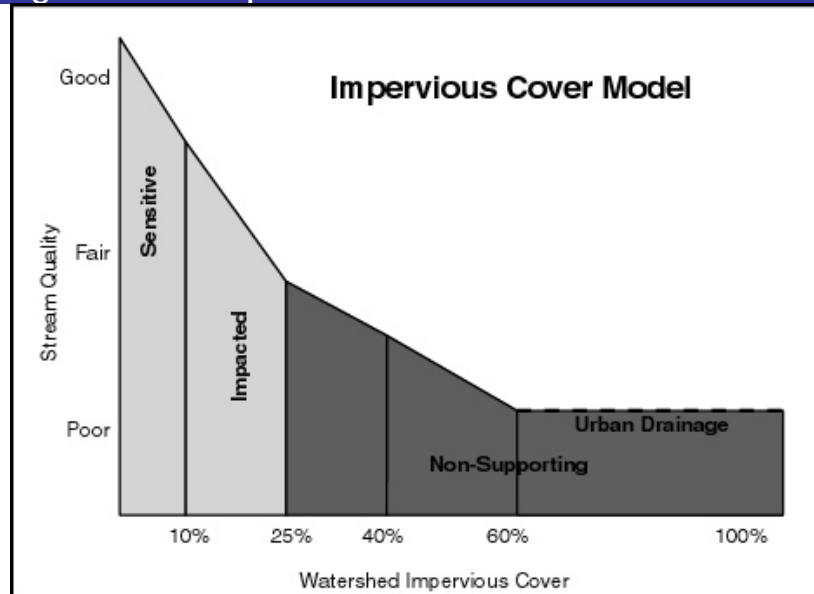
Flooding

The sheer volume of storm water runoff poses a problem in itself. According to Ewing (1996), it has been estimated that direct storm water runoff can increase eleven to nineteen times when woodlands are converted to high-density residential and commercial development. The influx of storm water runoff from impervious surfaces increases peak storm flows in surface waters, thereby increasing the frequency and severity of flooding (Barnes et al., 2001). The increase of storm water volumes produced by impervious surface runoff over natural storm water influx can cause flooding during relatively minor rain events and in streams where flooding did not occur before development of the surrounding area (Barnes et al.). In areas serviced by storm water sewers, peak discharge levels can increase eight-fold with 100 percent imperviousness (Barnes et al.).

Impervious Surfaces

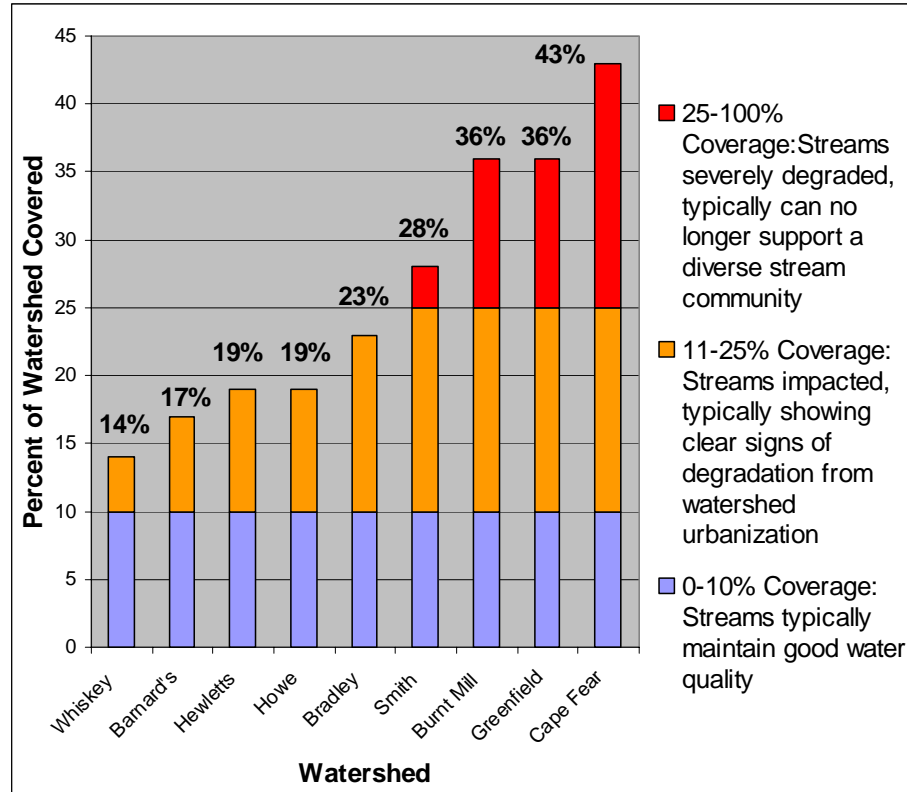
Naturally, the amount of pollutants entering a waterway in runoff from impervious surfaces increases as the impervious surface coverage in a watershed increases. According to the Center for Watershed Protection (1998), water quality in streams, lakes, and wetlands is negatively impacted when impervious surface coverage in a watershed exceeds just 10 percent. Additionally, according to the National Association of Local Government Environmental Professionals, when impervious surface coverage reaches 25%, as illustrated in Figure 3.4, waterways are typically no longer able to support healthy aquatic systems (Blaha, Cogan, Stein & Ward, 2003).

Figure 3.3 The Impervious Cover Model



As presented in Figure 3.5, The Smith, Burnt Mill, Greenfield, and Cape Fear River watersheds all have impervious surface coverages over 25%, while impervious surface coverage in Bradley Creek is just below this critical threshold. At 14%, Whiskey Creek watershed has the lowest impervious surface coverage, which indicates that there is no water body within the City limits that is not adversely impacted by the pollutants contained in storm water runoff.

Figure 3.4 Impervious surface coverage in Wilmington watersheds



North Carolina's Nonpoint Source Management Program, headed by the DWQ, is comprised of numerous state and local agencies and departments which inspect and permit activities and systems that may contribute to nonpoint source pollution, such as land clearing projects and septic systems. The Non-Discharge Permitting Unit (NDPU) reviews and issues permits for all systems using land application as a means for waste disposal, such as spray irrigation systems, and sanitary sewer collection systems.

4. Water Quality in Wilmington's Tidal Creeks

The following information about water quality in Wilmington's tidal creeks is drawn from data gathered by the DWQ, The New Hanover County/ UNCW Center for Marine Science Tidal Creeks Program, and The Lower Cape Fear River Program. All tidal creeks in Wilmington follow a general spatial water quality pattern. Water quality near the mouth of a tidal creek, where salinity and flushing are high, tends to be good. Water quality tends to decrease farther up the creek, with areas near the headwaters generally exhibiting the poorest water quality (Mallin, et al 1998a).

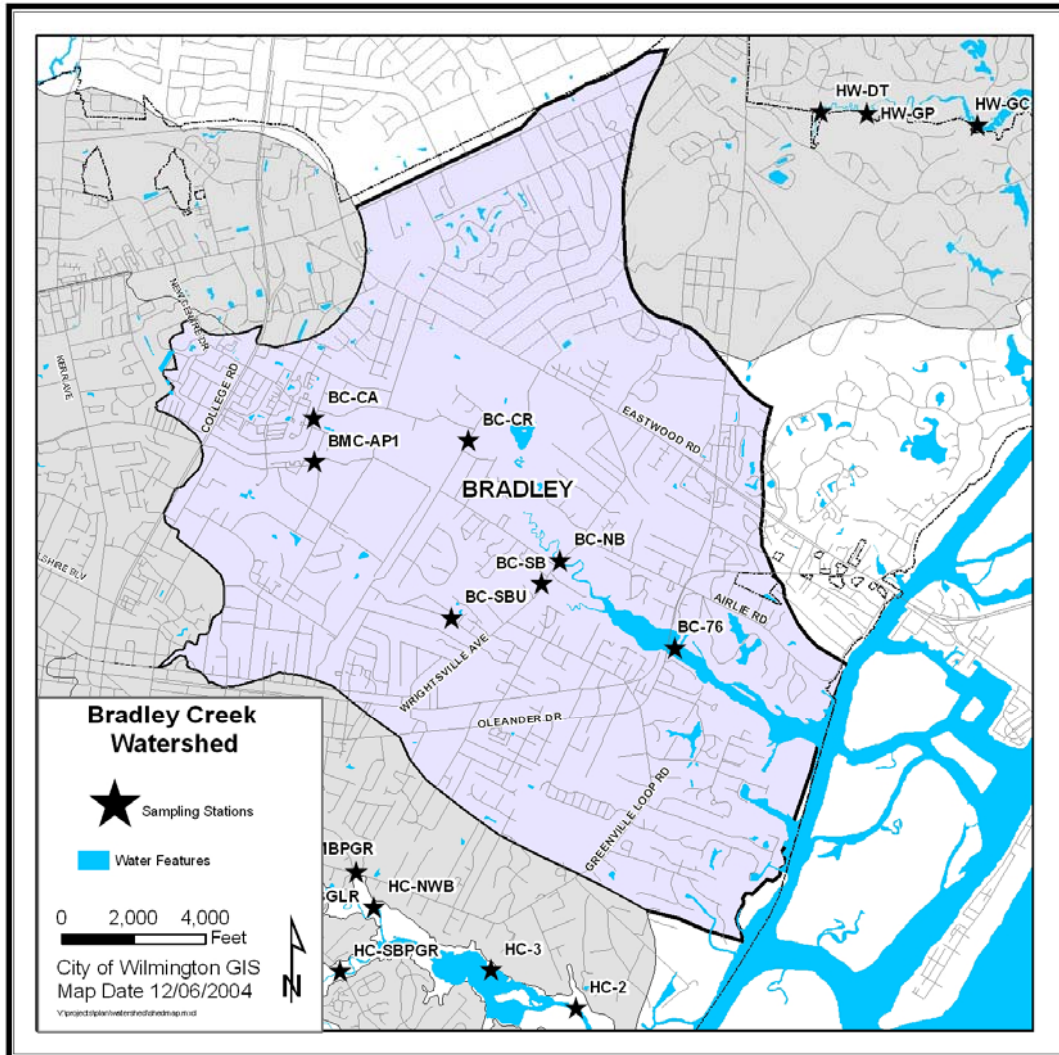
Table 4.1 Tidal Creek Summary

Name	Status	Shellfishing	Class	Notes
Bradley Creek	Impaired	N/A	SC, HQW	Largest watershed and most polluted tidal creek
Hewlett's Creek	Impaired	Closed	SA, HQW	Second largest and second most polluted tidal creek
Howe Creek	Impaired	Closed	SA, ORW	Third most polluted tidal creek
Whiskey Creek	Impaired	Closed	SA, HQW	
Lower Cape Fear River	Impaired	N/A	SC	Receives most point source discharge

4.1 Bradley Creek

Watershed Description

At **9.4 square-miles**, Bradley Creek watershed is the largest in Wilmington. It is also the most polluted. Bradley Creek flows directly into the Intracoastal Waterway.



Stations

BC-76: Nearest the mouth, at Military Cutoff Road

BC-SB: Downstream station in the South Branch of the creek

BC-SBU: Upstream station in the South Branch of the creek

BC-NB: Downstream station in the North Branch of the creek

BC-NBU: Upstream station in the North Branch of the creek

BC-CR: Station in the Center Branch of the creek, upstream from the North Branch, near UNCW

BC-CA: Uppermost station, at College Acres Apartments

Major Watershed Landmarks

Portions of Oleander Drive, Greenville Loop Road, College Road, Airlie Road, Eastwood Road, and UNCW.

State Classification

Bradley Creek is classified as a **High Quality SC** water body (NCDENR, *NC Water Bodies*), which means the creek should be in excellent biological and chemical health and be able to support aquatic life (including shellfish for non-market purposes), wildlife, and secondary recreation. Currently, Bradley Creek is **not supporting** of these intended uses (aquatic life, secondary recreation). Bradley Creek is listed in the 2004 North Carolina Water Quality Assessment and Impaired Waters List (2004 Integrated 305(b) and 303(d) Report) under the Division of Environmental Health's Shellfish Sanitation assessment unit B7 (Wrightsville Beach Area). The B7 area is included in Category 7 of the Impaired Waters List, which means it is a high-priority clean up area, but an area for which the proper technical conditions to develop a remediation strategy (Total Maximum Daily Load or TMDL) do not currently exist (NCDENR, 2004).

Primary Land Uses

More than a third of the Bradley Creek watershed is residential land. The next largest land use category is vacant land or land for which the use is unknown. Office and institutional uses are also significant within the watershed. Other uses include mobile home, commercial, recreation, and multi-family. There is very little utility, agricultural, or industrial use in the Bradley Creek watershed. Within the critical 1000-foot buffer zone along the creek, single family residential and recreational uses are the most prevalent, with vacant lands and lands for which the use is unknown also contributing a significant percentage.

Figure 4.1.1 Bradley Creek – Land use in the watershed

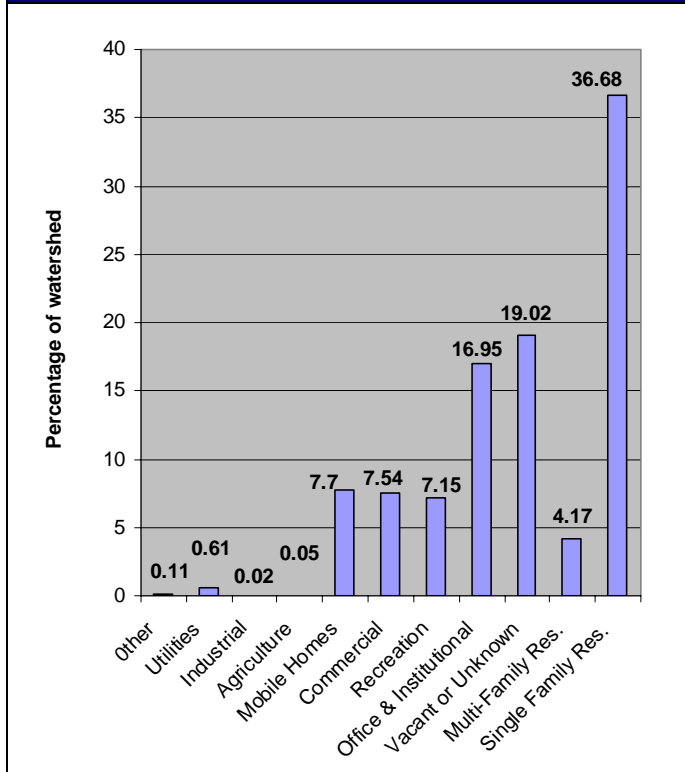
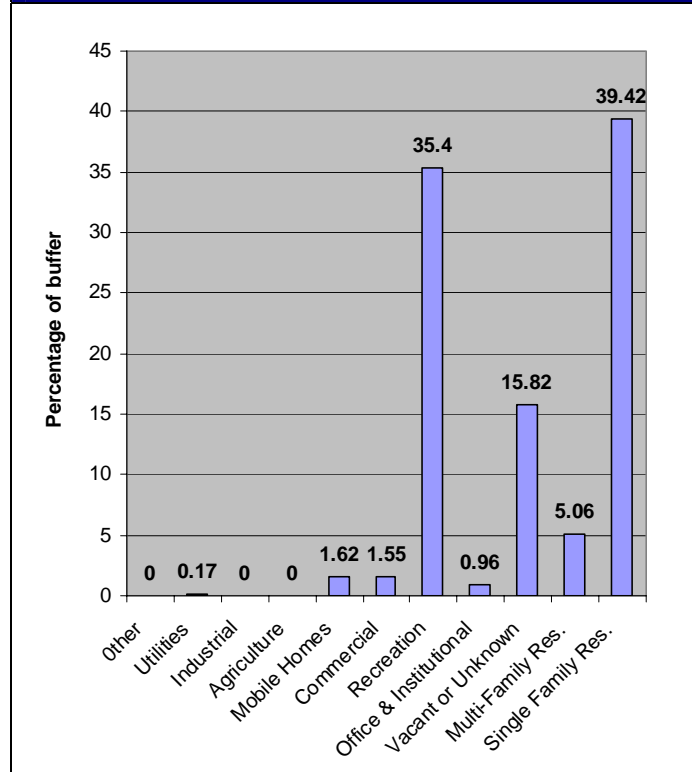


Figure 4.1.2 Bradley Creek – Land use in the 1000-foot buffer

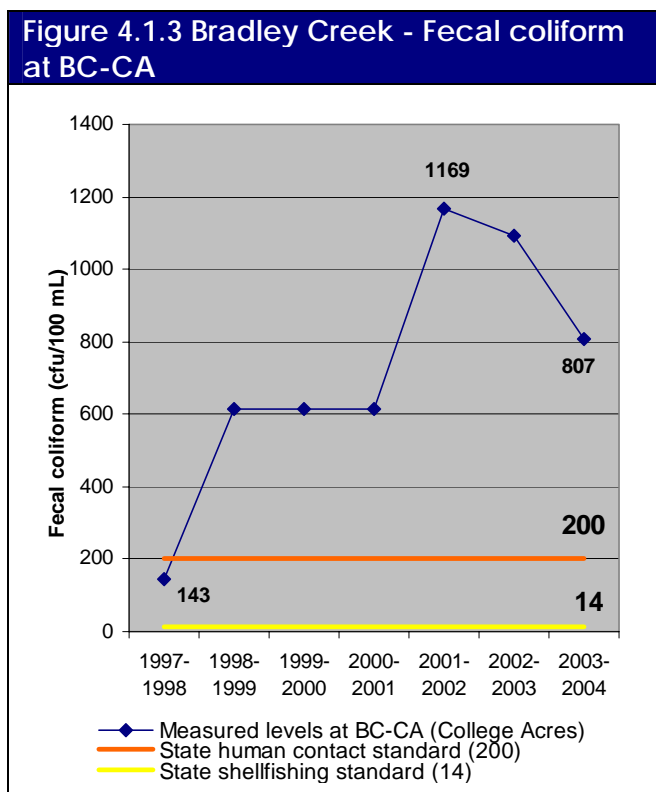


Major Pollutants and Water Quality Impacts

Bradley Creek is the most heavily impacted tidal creek in Wilmington (NCDENR, 1999) and one of the most polluted creeks in New Hanover County (Mallin, Cahoon, Posey, Johnson, et al.,

2004). The Bradley Creek watershed is entirely contained within the city limits. Twenty-three percent of the land area in the Bradley Creek watershed is covered with impervious surfaces. This is the highest percentage of all the tidal creeks, excluding the Cape Fear River. Consequently, Bradley Creek also exhibits the highest geometric mean fecal coliform counts of all the tidal creeks.

Fecal coliform bacteria: Fecal coliform bacteria is a major pollutant in Bradley Creek, with 82% of samples exceeding the State standard for human contact of 200 CFU/100mL between August 2002 and July 2003 at a sampling station near College Acres (Mallin et al., 2004). Fecal coliform bacteria come from human or animal waste (including pet waste). Major sources of waste entering Bradley Creek are pet wastes left on the ground and washed into the creek by storm water, sewer collection system failures, and on-site wastewater system failures (NCDENR, 2004). The majority of Bradley Creek has been closed to shellfishing due to fecal coliform bacteria contamination since 1947 (Sabo, 2004b). It was one of the first creeks in Wilmington to be closed due to fecal coliform contamination, which contributed to its classification as an SC waterbody. Fecal bacterial counts at the College Acres sampling station in Bradley Creek in 2003 were frequently high enough to **pose a serious potential health threat** from bodily contact with these waters (Mallin et al, 2004).



Nutrients: Nutrient loading - an over abundance of nitrogen and phosphorous that can stress the aquatic ecosystem, cause harmful algal blooms, decrease dissolved oxygen levels and cause fish kills - has been a major problem in Bradley Creek (Mallin et al., 1998b). Nitrate and phosphate levels at the College Acres station spiked (figures 4.1.5 and 4.1.7) two years ago, likely due to the breaking of the draught (Mallin et al, 2004). Nitrate levels at a station near UNCW (BC-CR) have remained consistently above the suggested level for nitrate. Some sampling areas also exhibited higher phosphate levels and ammonium levels

and lower dissolved oxygen in 2002-2003 (Mallin et al, 2004). Though phosphate levels have risen, no sampling station exceeded the phosphate level of 0.1 mg/L considered acceptable by the DWQ.

Figure 4.1.4 Bradley Creek – Nitrate at all stations except BC-CA

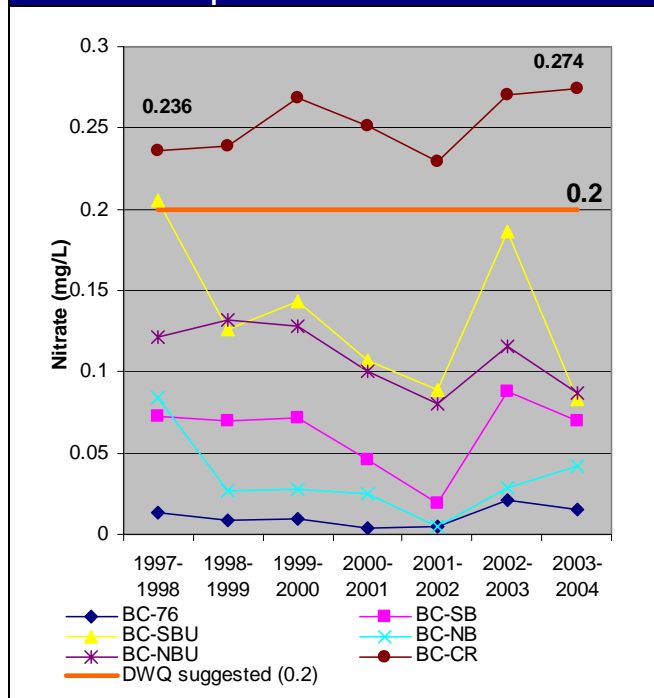


Figure 4.1.5 Bradley Creek – Nitrate at station BC-CA

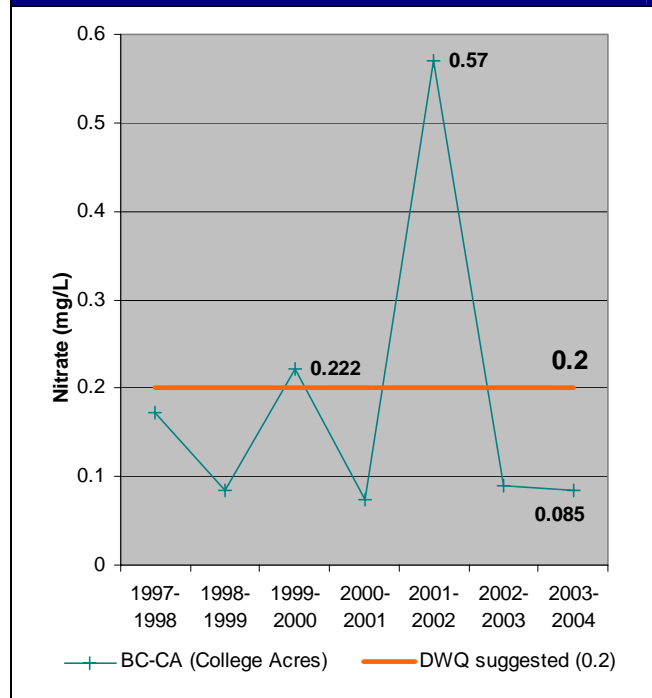


Figure 4.1.6 Bradley Creek – Phosphate at all stations except BC-CA

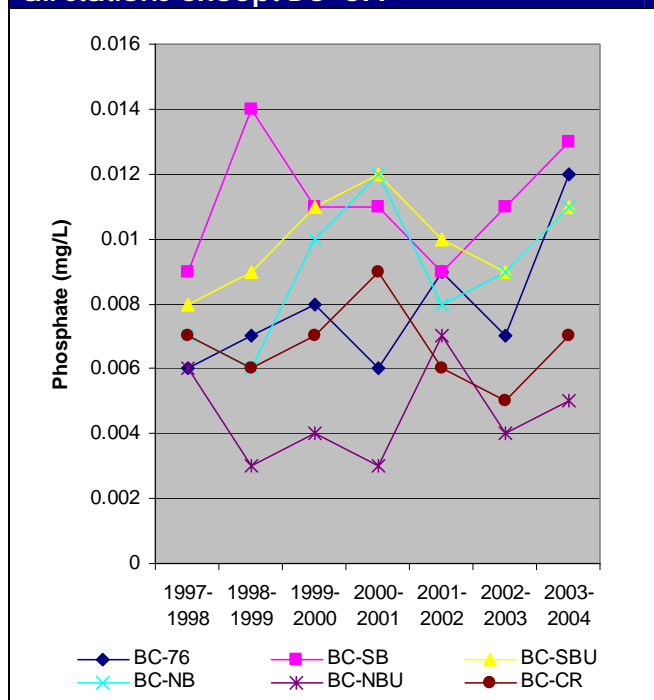
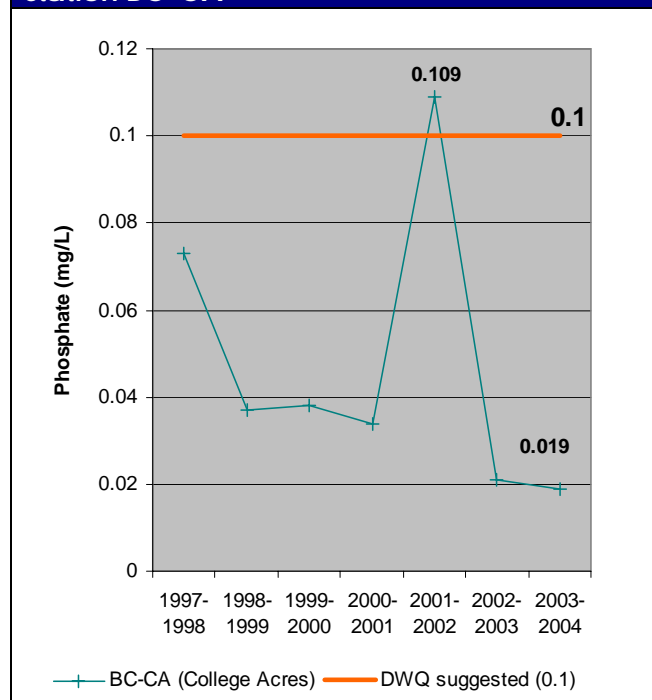
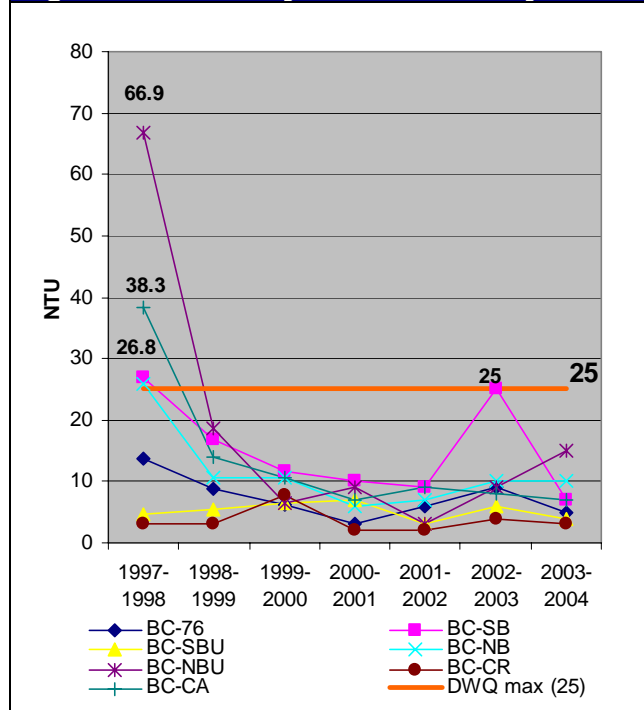


Figure 4.1.7 Bradley Creek – Phosphate at station BC-CA



Sediment: Turbidity, caused by sediment-loaded runoff from construction activities, has also been a major problem in the past (Mallin et al, 1998b), but has generally abated in the last several years (Mallin et al, 2003 and 2004). However, turbidity levels at station BC-SB, the lower South Branch station, have increased in the last two years.

Figure 4.1.8 Bradley Creek - Turbidity



Watershed Goals

Perpetual

Restore and maintain water quality in Bradley Creek so that the creek is able to support the uses designated by its classification as a High Quality SC waterbody.

- Restore and maintain water quality suitable for secondary recreation, such as boating, fishing, and infrequent swimming.
- Restore and maintain water quality necessary to restore and maintain a healthy aquatic environment.

Long-term

- Reduce bacterial pollution in Bradley Creek.
 - Reduce fecal coliform bacteria pollution at all stations to levels consistent with NCDENR state standards for human contact (200 colony forming units per 100 milliliters of water).
- Reduce nutrient loading in Bradley Creek.
 - Reduce nitrate at all stations to levels consistent with NCDENR's DWQ suggested maximum (0.2 milligrams per Liter).
- Manage all other water quality parameters, including phosphate, ammonium, dissolved oxygen and turbidity, to be maintained at their appropriate levels.

Concerns

Fecal coliform
Nutrients
Sediments

Sources

Urban storm
water runoff
Collection
system failures
Onsite
wastewater
systems

Short-term

- 1) Address fecal coliform levels in the College Acres area.
- 2) Address nitrate levels in the UNCW area.
- 3) Address increasing turbidity in the lower South Branch of Bradley Creek.

Opportunities for Protection, Restoration, and Education

Bacterial Pollution:

- Public education about impervious surface proliferation
- Efforts to reduce impervious surfaces (in new development, through redevelopment, legislation, other?)
- Public education about pet waste clean up
- Attention to sewer collection system failures (how?)
- Attention to on-site waste water treatment system failures (how?)

Nutrient Loading:

- Improve storm water Best Management Practices (BMPs) at selected sites to increase nutrient uptake

Other:

- Reduce erosion, turbidity, and sedimentation through stream bank stabilization along selected parts of the creek

Completed Protection Efforts

- **Airlie Gardens:** In 1999, with funding from the Clean Water Management Trust Fund, the New Hanover County Tidal Creeks Program purchased Airlie Gardens to serve as “a buffer along Bradley Creek as well as an outdoor laboratory and educational site” (New Hanover County [NHC], 2002). The program is “actively seeking” acquisition of riparian buffer lands and conservation easements along Bradley Creek to reduce impervious surfaces and restore riparian areas (NHC, 2002).

On-going Protection Efforts

- **NCDENR:** A special management strategy to limit discharges to Bradley Creek will be introduced in the 2005 Basinwide Assessment Report for the Cape Fear River Basin (McNutt, 2004, April 23). Details of the management strategy are not yet available.
- **Duckhaven Golf Course:** The New Hanover Tidal Creeks Program is negotiating with the owners of a 150-acre property at the juncture of Three-Mile Branch and Clear Run to purchase approximately 8.5 acres for use as natural riparian buffer. The Program is also hoping to help the developers of the property use Best Management Practices in order to help reduce and treat storm water runoff from this property and an adjacent development (UNCW 2005).
- **Mayfaire:** Approximately 4 acres in the Bradley Creek watershed were dedicated as open space.

Other Protection Effort Opportunities

- **Clear Run Branch and South Branch:** Stream bank stabilization projects along parts of these two branches provide opportunities to reduce erosion of the stream channel, reduce sedimentation, and create habitat favorable to healthy aquatic life.
- **College Road:** Storm water Best Management Practices (BMP) retrofits at selected sites in the College Road area provide opportunities to create areas where sediments may be

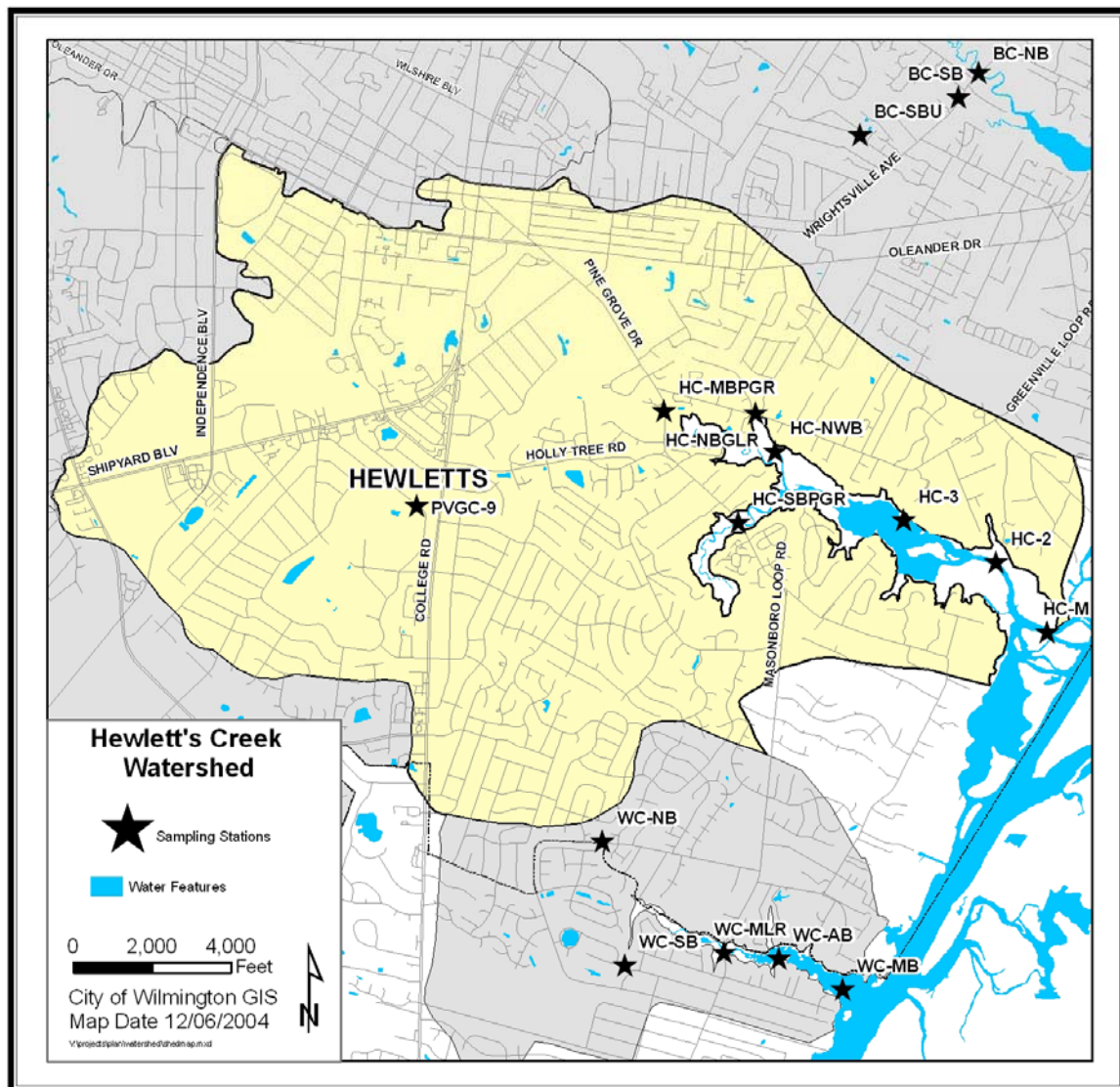
collected from storm water and where nutrients and heavy metals may be filtered by aquatic plants.

- **UNCW:** There are opportunities on the UNCW property for stream bank stabilization and restoration to reduce erosion, sedimentation, and to provide habitat. Updating BMPs on the UNCW property would also help collect sediment and aid in the removal of nutrients and metals.

4.2 Hewlett's Creek

Watershed Description

Hewlett's Creek, at **9.3 square-miles**, is the second largest and second most polluted watershed in Wilmington. Hewlett's Creek also flows directly into the Intracoastal Waterway.



Stations

HC-2: Nearest the mouth
HC-3: Upstream from the mouth
NB-GLR: North Branch, closest to Oleander Drive
SB-PGR: South Branch
MB-PGR: Middle Branch, near Pine Valley Country Club and golf course
PVGC-9: Pine Valley Golf Course

Major Watershed Landmarks

"Independence Boulevard, Shipyard Boulevard, South College Road, Oleander Drive, Masonboro Loop Road, Municipal Golf Course, Westfield Shopping Mall, Long Leaf Mall, and Hugh McCrae Park" (City of Wilmington, 2004).

State Classification

Hewlett's Creek is classified as a **High Quality SA** water body (NCDENR, *NC Water Bodies*), which means the creek should be in excellent biological and chemical health. SA waters should support aquatic life, both primary and secondary recreation (activities with frequent or prolonged skin contact), and shellfishing for market purposes. Hewlett's Creek is **not supporting** these intended uses. Hewlett's Creek is listed in the 2004 North Carolina Water Quality Assessment and Impaired Waters List (2004 Integrated 305(b) and 303(d) Report) under the Division of Environmental Health's Shellfish Sanitation assessment unit B6 (Masonboro Sound Area). The B6 area is a medium-priority area included in Category 7 of the Impaired Waters List, but an area for which the proper technical conditions to develop a remediation strategy (Total Maximum Daily Load or TMDL) do not currently exist (NCDENR, 2004). Hewlett's Creek is **closed to shellfish harvesting** for all of the creek except near the mouth (Sabo, 2004b).

Primary Land Uses

More than half of the land in Hewlett's Creek watershed is used for single family residential. Vacant land and lands for which the use is unknown constitute the next most prevalent land use. Recreation, office and institutional, and commercial uses each account for approximately the same amount of land. Multi-family residential, mobile homes, utility, and industrial uses are the least prevalent uses in the Hewlett's Creek watershed.

Figure 4.2.1 Hewlett's Creek – Land use in the watershed

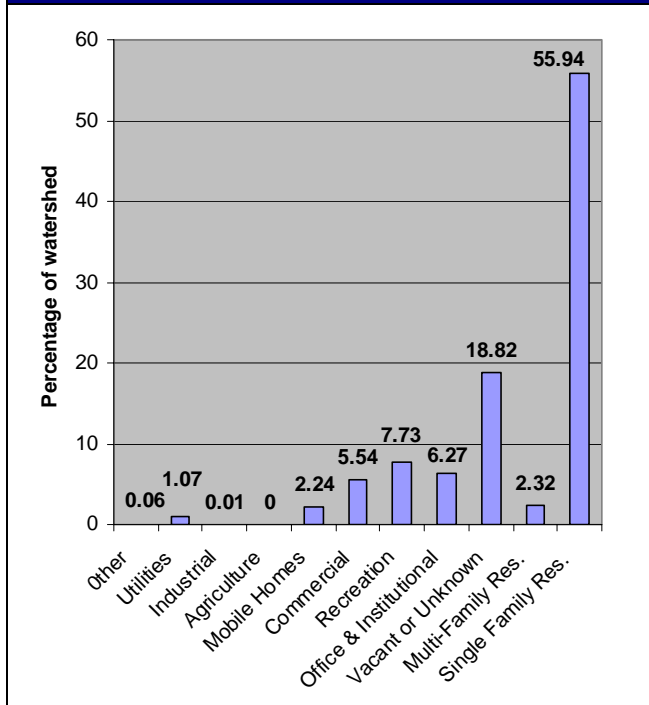
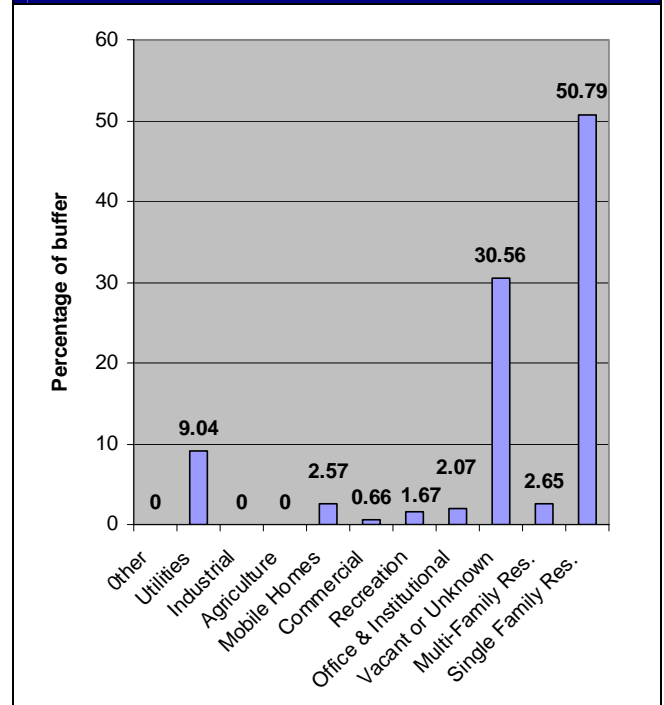


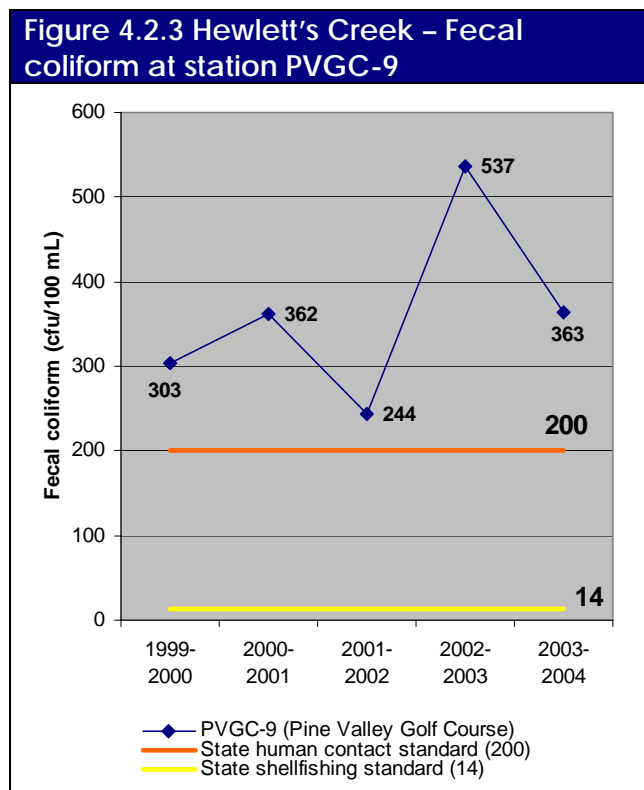
Figure 4.2.2 Hewlett's Creek – Land use in the 1000-foot buffer



Major Pollutants and Water Quality Impacts

Hewlett's Creek is the second most impacted water body in Wilmington, after Bradley Creek. Increasing local urbanization and resultant runoff have heavily impacted both creeks (NCDENR, 1999). The Hewlett's Creek watershed is approximately 19% impervious surface. A major sewer pipeline failure resulted in the discharge of an estimated three million gallons of untreated sewage into the Creek in July 2005. Fecal coliform levels skyrocketed to as high as 270,000 colonies per 100 ml before falling back down. The long term effects of this release are not known.

Fecal coliform bacteria: Fecal coliform bacteria is a major pollutant in Hewlett's Creek, and has caused the majority of the creek to be closed to shellfishing since 1974 (Sabo, 2004b). The sampling station near the Pine Valley Country Club is the only station that is routinely sampled for fecal coliform since this station is where fecal coliform is the most severe. Seventy-five percent of samples taken in 2002-2003 at this station exceeded State fecal coliform standard levels (Mallin et al, 2004). Urban runoff is the main source of fecal coliform bacteria contamination in Hewlett's Creek (NCDENR, 2004).



Nutrients: High nitrate and phosphate concentrations have been a continuous problem in Hewlett's Creek (Mallin et al, 1998a-2004). Nitrate levels have been consistently higher in the middle branch of Hewlett's Creek (PVGC-9), which drains the Pine Valley subdivision and the Municipal Golf Course, and have increased between 2001 and 2003 (Mallin et al, 2004). Agricultural fertilizer is another source of the nutrients washing into Hewlett's Creek. Hewlett's Creek has also had the highest overall phosphate levels of all the tidal creeks (Mallin et al, 1998b), though none of the sampling stations, except PVGC-9 exceeded the DWQ suggested level of 0.1 mg/L (Figure 4.2.6). Nutrient loading has caused frequent algal blooms in the creek since at least 1998 (Mallin et al, 1998b; 1999; 2002). One major and several minor algal blooms occurred in April, June, and July, 2003

(Mallin et al, 2004). Algal blooms deplete the dissolved oxygen in water and can lead to fish kills.

Figure 4.2.4 Hewlett's Creek – Nitrate at selected stations

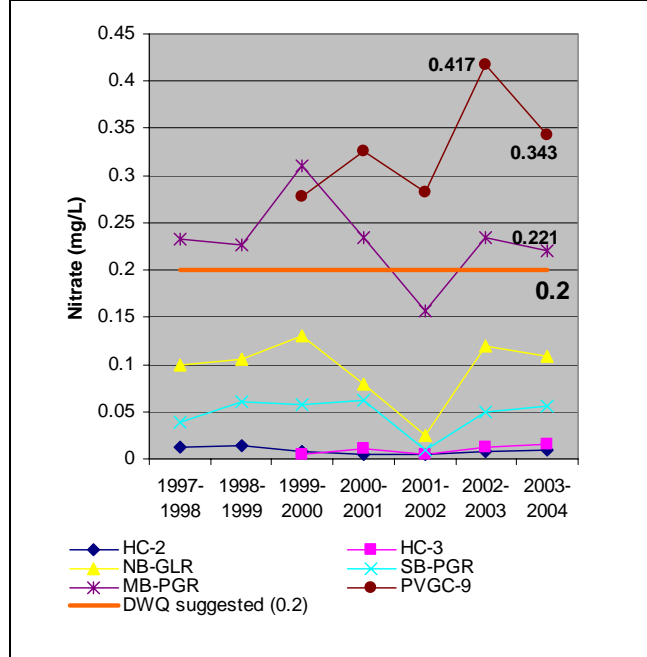


Figure 4.2.5 Hewlett's Creek – Phosphate at selected stations

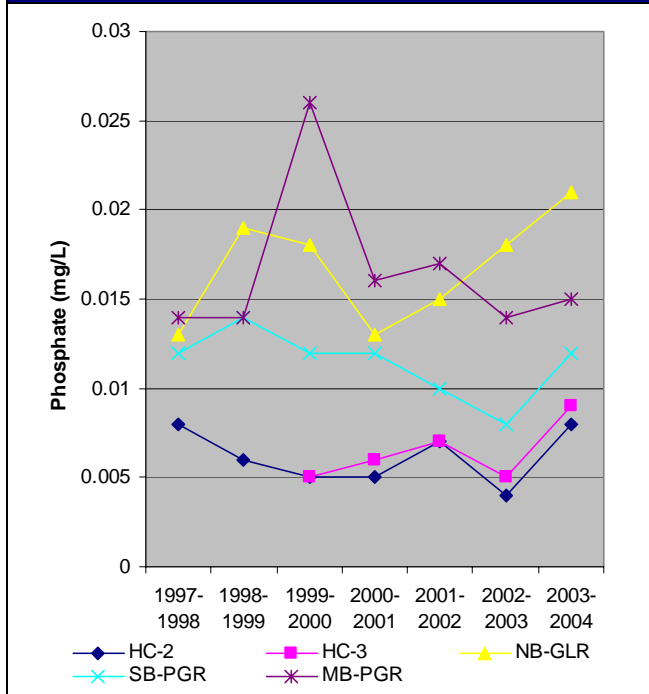
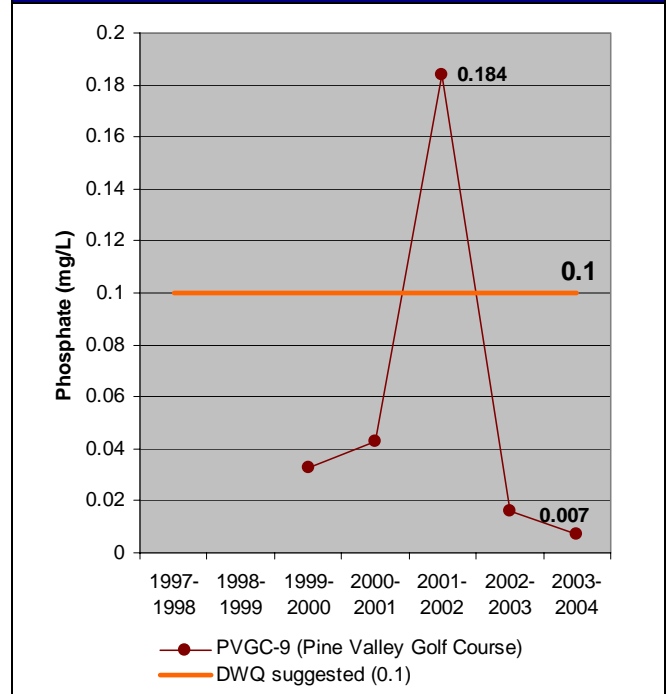


Figure 4.2.6 Hewlett's Creek – Phosphate at station PVGC-9



Watershed Goals

Perpetual

Restore and maintain water quality in Hewlett's Creek so that the creek is able to support the uses designated by its classification as a High Quality SA waterbody.

- Restore and maintain water quality suitable for primary recreation, such as swimming, and secondary recreation, such as fishing and boating.
- Restore and maintain water quality necessary to sustain a healthy aquatic environment and that will allow shellfishing for market purposes.

Concerns

Fecal coliform
Nutrients

Sources

Urban storm
water runoff
Agriculture
Marinas

Long-term

1) Reduce bacterial pollution in Hewlett's Creek.

- Reduce fecal coliform bacteria pollution at all stations to levels consistent with NCDENR state standards for shellfishing (14 colony forming units per 100 milliliters of water).

2) Reduce nutrient loading in Hewlett's Creek.

- Reduce nitrate at all stations to levels consistent with NCDENR's DWQ suggested maximum (0.2 milligrams per Liter of water).
- Control/ prevent algal blooms.

3) Manage all other water quality parameters, including phosphate, ammonium, dissolved oxygen and turbidity, to be maintained at their appropriate levels.

Short-term

1) Address fecal coliform levels in the Pine Valley Country Club area.

2) Address nitrate levels in the Pine Valley Country Club area.

Opportunities for Protection, Restoration, and Education

Bacterial Pollution:

- Measures to prevent a repeat of the July 2005 sewage release
- Public education about impervious surface proliferation
- Efforts to reduce impervious surfaces (in new development, through redevelopment, legislation, other?)
- Public education about pet waste clean up

Nutrient Loading:

- Public education about fertilizer use.
- Restore channelized areas to a more natural meandering structure to increase nutrient uptake.

Other:

- Reduce erosion, turbidity, and sedimentation through stream bank stabilization along selected parts of the creek

Completed Protection Efforts

- **Pine Valley Golf Course:** The City constructed a retention pond at Pine Valley Golf Course in 1990 to trap nutrients from the golf course and reduce fecal coliform loads (City of Wilmington, *Capital*).

- **Long Leaf Creek:** In 1998 the Long Leaf Creek Stream Bank Stabilization project was completed by the City to repair and strengthen 1500 feet of severely eroded stream that feeds Hewlett's Creek (Mayes 2004, May 20).
- **Park Avenue:** Four bioretention areas were completed in 2001 along Park Avenue. These bioretention areas were installed to treat runoff from a road improvement project (City of Wilmington, *Capital*).
- **Pine Valley Golf Course:** In 2001, approximately 1000 feet of a ditch along the Pine Valley Golf Course was converted to a natural stream pattern and stabilized with stream bank vegetation. The ditch had been severely eroded and served to carry sediment, nutrients, and other pollutants from the golf course to Hewlett's Creek. This project was a joint effort between the City, Pine Valley Country Club, NC Sea Grant, NHC Tidal Creeks Program, and NC Wetlands Restoration Program and was completed with the use of Clean Water Management Trust Fund money. In addition, numerous educational presentations to members of the country club increased awareness of members' impacts on runoff and storm water pollution (UNCW 2005).

On-going Protection Efforts

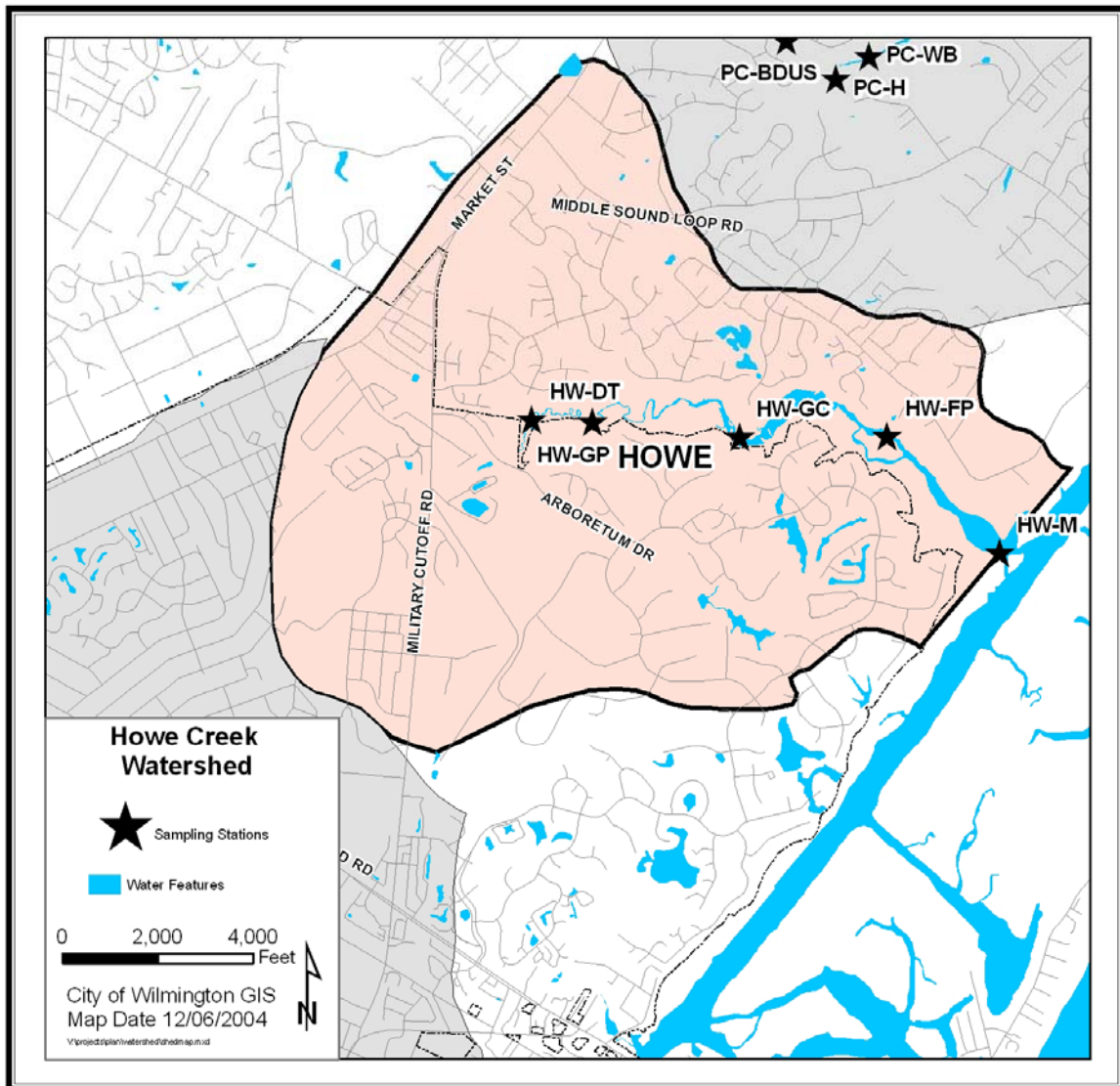
- **Greenville Loop Road:** The City is currently constructing a 50-foot span bridge on Greenville Loop Road to replace aging culverts, a concrete end wall, and a wooden bulkhead. The intent is to improve tidal flushing in the upper portions of Hewlett's Creek and improve local drainage (City of Wilmington, 2004).
- **Hewlett's Creek Greenway:** The New Hanover Soil and Water Conservation District, in partnership with the City of Wilmington's Storm Water Services Division and the New Hanover County Tidal Creeks Program, has received Clean Water Management Trust Fund money to purchase undeveloped property along Hewlett's Creek. The Soil and Water Conservation District has also obtained conservation easements to help create the greenway (Soil and Water Conservation District).
- **Riley's Branch:** Riley's Branch, a tributary of Hewlett's Creek, is severely incised and the City's Storm Water Services Division has received funding for stabilization using bioengineering and vegetation. The project is not yet scheduled for construction (Mayes, 2004, May 20).
- **Dobo Property:** The City of Wilmington Storm Water Services Division and the New Hanover County Tidal Creeks Program has acquired 16 acres of vacant land in the Hewlett's Creek watershed. A regional passive storm water treatment facility will be constructed on this site and will combine a wet detention pond and a storm water wetland. This project will serve a drainage area containing over 1,500 homes and will reduce nutrient loading and fecal coliform inputs to Hewlett's Creek and help control floodwaters. A request has been submitted to the Clean Water Management Trust Fund for reimbursement of acquisition costs (UNCW 2005).
- **Toomer's Creek:** The Hewlett's Creek Greenway is a joint project of the City, the NHC Tidal Creeks Program, and the NHC Soil and Water Conservation District. The project seeks to preserve undeveloped land along Hewlett's Creek, particularly along the 55-acre stretch encompassing Toomer's Creek. The NHC Soil and Water Conservation District has submitted a Clean Water Management Trust Fund grant proposal for the purchase of a .79 acre parcel at South College Road and Holly Tree Road on which to begin the greenway project (City of Wilmington, 2004).
- **Pine Valley Golf Course:** The City and the North Carolina Ecosystem Enhancement Program of NCDENR, have received funding to conduct a natural stream restoration at the Pine Valley Golf Course. The project has not yet been scheduled (Mayes, 2004, April).

- **Long Street:** The City has received funding for stabilization of a channel in the Pine Valley neighborhood using native vegetation. The project has not yet been scheduled (Mayes, 2004, May 20).
- **Tidal Creek Buffer Program:** The New Hanover Soil & Water Conservation District is in the process of setting up this program to provide 75% cost share assistance, as well as technical assistance, to land owners who wish to voluntarily engage in the restoration and enhancement of riparian buffers along Hewlett's Creek. The funding from the Federal Wetlands Reserve Program for this program is pending.
- **Upgrades to City Sewer System:** The City is currently evaluating the collection system to develop options for designing backup measures into the system to prevent future releases.

4.3 Howe Creek

Watershed Description

Howe Creek is the fourth largest watershed in Wilmington, encompassing 5.1 square-miles. Howe Creek flows into the Intracoastal Waterway.



Stations

- HW-M: At the mouth of the creek
- HW-FP: Upstream from the mouth of the creek
- HW-GC: Mid-creek station, downstream from Graham Pond
- HW-GP: Graham Pond
- HW-DT: Uppermost station, upstream from Graham Pond

Major Watershed Landmarks

A portion of Military Cutoff Road and the newly constructed Mayfaire community and town center.

State Classification

Howe Creek is classified as a **High Quality SA** water body (NCDENR, *NC Water Bodies*), which means the creek should be in excellent biological and chemical health. SA waters should support aquatic life, both primary and secondary recreation (activities with frequent or prolonged skin contact), and shellfishing for market purposes. Howe Creek is **not supporting** of these intended uses. Howe Creek is listed in the 2004 North Carolina Water Quality Assessment and Impaired Waters List (2004 Integrated 305(b) and 303(d) Report) under the Division of Environmental Health's Shellfish Sanitation assessment unit B7 (Wrightsville Beach Area). The B7 area is a high-priority area included in Category 7 of the Impaired Waters List, but an area for which the proper technical conditions to develop a remediation strategy (Total Maximum Daily Load or TMDL) do not currently exist (NCDENR, 2004). The majority of Howe Creek is currently **closed to shellfish harvesting** (Sabo, 2004a).

Primary Land Uses

Nearly half of the land within the Howe Creek watershed is either vacant or is of unknown use. Single family residential accounts for a third of the land use. Recreation use in the Howe Creek watershed is slightly higher than the other tidal creeks. Office and institutional, commercial, mobile home, multi-family residential, utilities, and industrial uses each contribute a small percentage to the overall land use of the Howe Creek watershed.

Figure 4.3.1 Howe Creek – Land use in the watershed

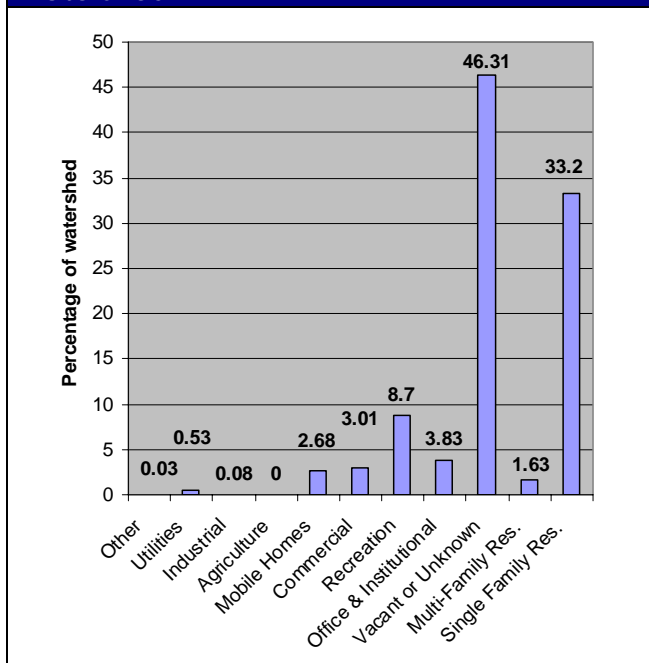
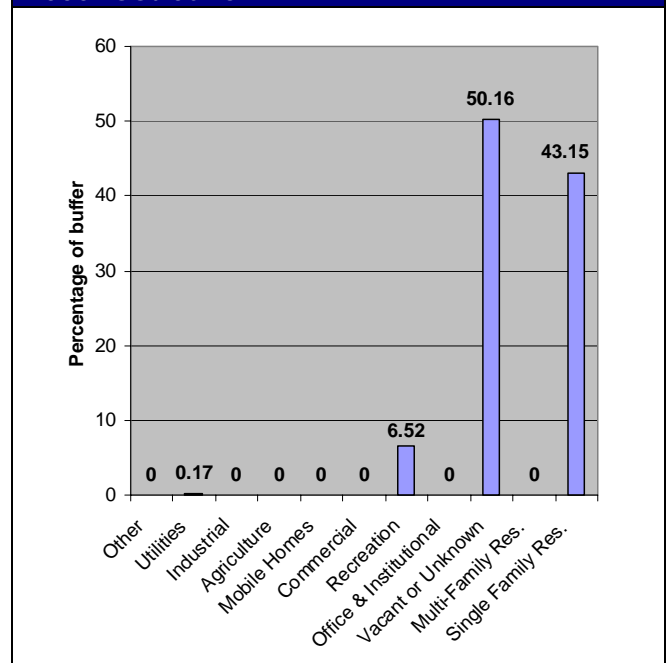


Figure 4.3.2 Howe Creek – Land use in the 1000-foot buffer



Major Pollutants and Water Quality Impacts

Howe Creek has been moderately impacted by local urbanization (Mallin et al 1998b). Along with runoff, collection system failures, and wastewater systems, construction along Military Cutoff Road has been a major source for pollutants entering Howe Creek. The wetlands enhancement project completed in the upper portion of Graham Pond and runoff mitigation efforts at the Mayfaire construction site have contributed to an overall increase in water quality

over the last few years. Like Hewlett's Creek, the Howe Creek watershed is 19% covered by impervious surfaces. Howe Creek is the third most impacted tidal creek, after Hewlett's Creek.

Fecal coliform bacteria: Fecal coliform levels have generally dropped since completion of the wetlands enhancement project in 1998 in the upper portion of Graham Pond. All stations, with the exception of HW-DT, the station upstream from Graham Pond, remain below the state human contact standard, though three of the five stations remain above the state standard for shellfishing. Fecal coliform levels have increased slightly in the downstream stations in the last two years. The Mayfaire project's runoff mitigation measures appear to have prevented large amounts of polluted runoff from reaching the creek (Mallin et al, 2004). Howe Creek was first closed to shellfishing between 1973 and 1977 and has been entirely closed to shellfishing since 1991 (Sabo, 2004b).

Figure 4.3.3 Howe Creek – Fecal coliform at selected stations

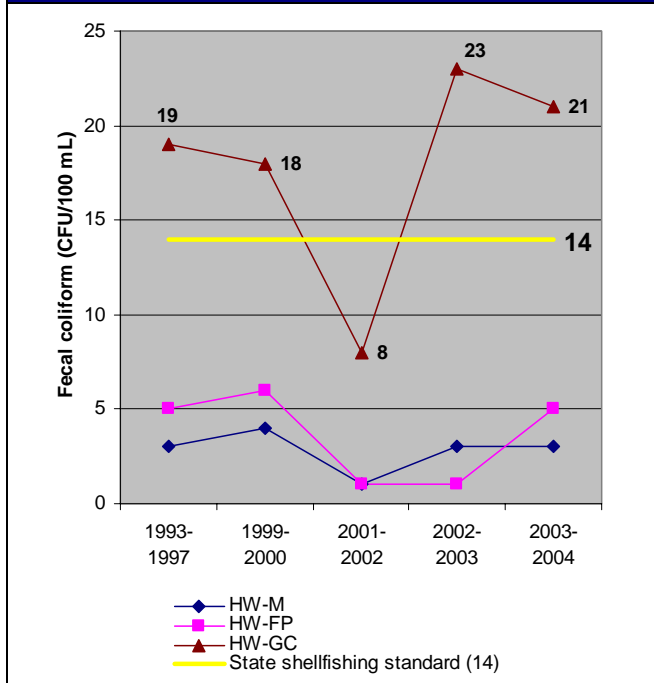
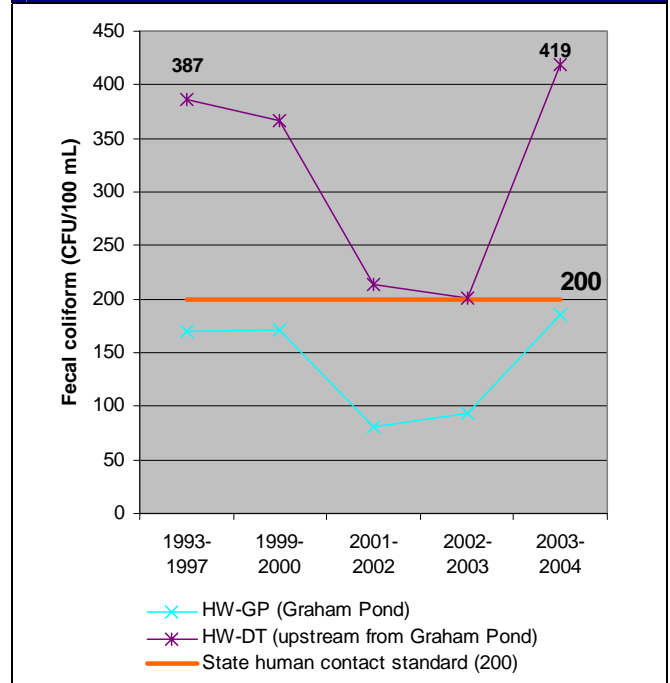


Figure 4.3.4 Howe Creek – Fecal coliform at Graham Pond stations



Nutrients: Nutrient loading has been a concern in Howe Creek in the past, with large algal blooms occurring near Graham Pond. After the wetlands enhancement project was completed in 1998, increasing water retention periods and allowing more uptake of nutrients by wetland vegetation, nutrient levels in the creek have decreased and generally stabilized and algal blooms have become less frequent and less severe (Mallin et al, 2004). Nitrate levels have risen in the last two years, but all stations remain well below the DWQ suggested nitrate level of 0.1 mg/L. Phosphate levels have also generally decreased since the wetland enhancement program, with all stations remaining well below the DWQ suggested level of 0.1 mg/L. Nitrate and phosphate levels at stations HW-GP (Graham Pond) and HW-DT (upstream of Graham Pond), the two stations closest to Military Cutoff Road, are consistently higher than levels at stations farther downstream.

Figure 4.3.5 Howe Creek – Nitrate at continuously monitored stations

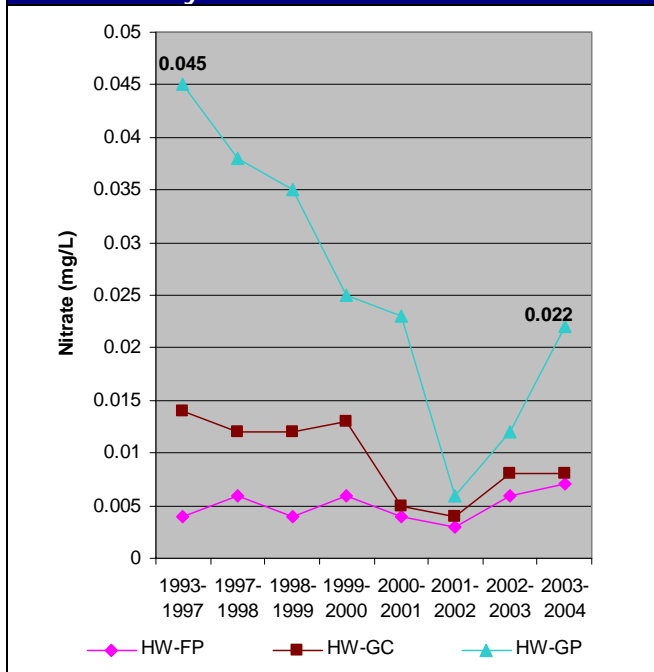


Figure 4.3.6 Howe Creek – Nitrate at periodically monitored stations

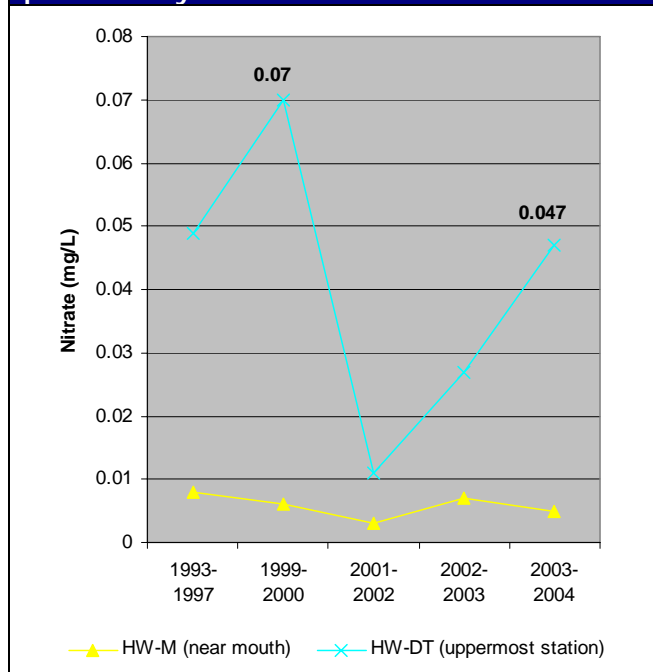


Figure 4.3.7 Howe Creek – Phosphate at continuously monitored stations

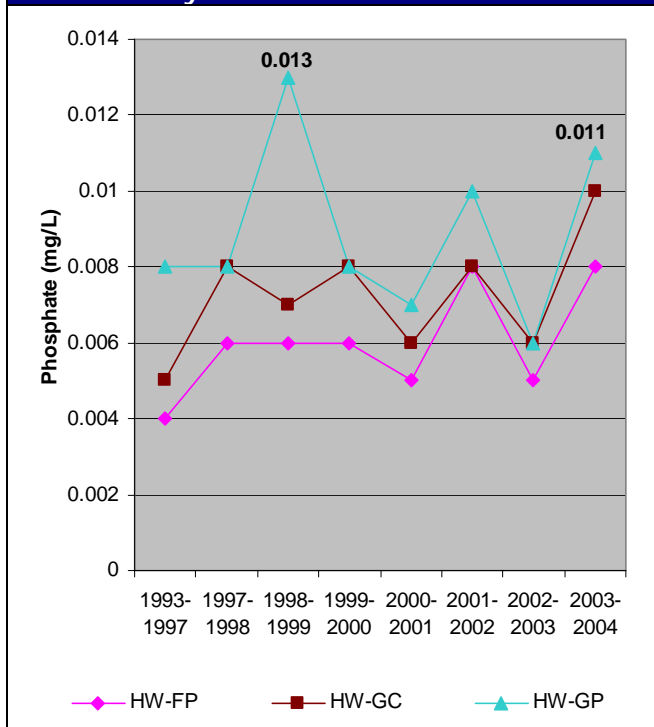
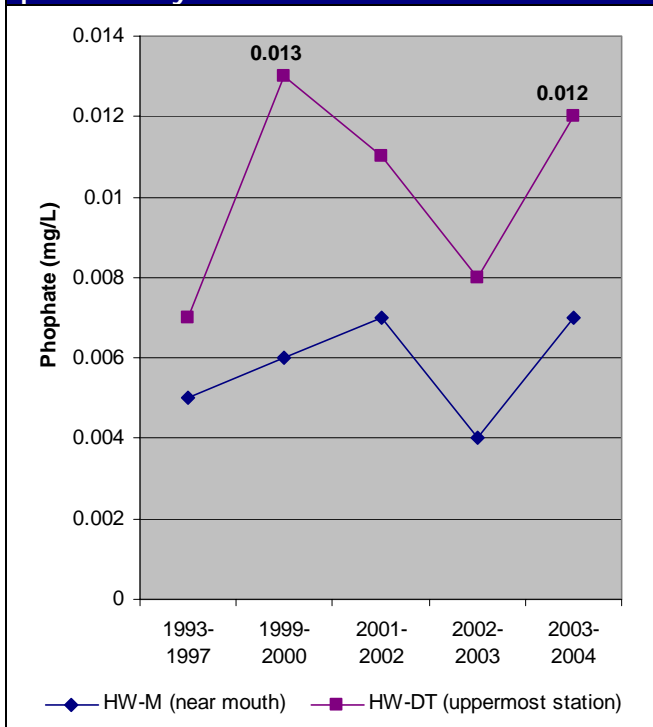


Figure 4.3.8 Howe Creek – Phosphate at periodically monitored stations



Watershed Goals

Perpetual

Restore and maintain water quality in Howe Creek so that the creek is able to support the uses designated by its classification as a High Quality SA waterbody.

- Restore and maintain water quality suitable for primary recreation, such as swimming, and secondary recreation, such as fishing and boating.
- Restore and maintain water quality necessary to sustain a healthy aquatic environment, such as one that would allow shellfishing for market purposes.

Concerns

Fecal coliform
Nutrients

Sources

Urban storm
water runoff
Collection
system failures
Onsite
wastewater
systems
Construction

Long-term

- 1) Reduce bacterial pollution in Howe Creek.
 - Reduce fecal coliform bacteria pollution at all stations to levels consistent with NCDENR state standards for shellfishing (14 colony forming units per 100 milliliters of water).
- 2) Reduce nutrient loading in Howe Creek.
 - Reduce nitrate at all stations to levels consistent with NCDENR's DWQ suggested maximum (0.2 milligrams per Liter of water).
 - Control/ prevent algal blooms.
- 3) Manage all other water quality parameters, including phosphate, ammonium, dissolved oxygen and turbidity, to be maintained at their appropriate levels.
- 4) Recreate a natural buffer along the length of Howe Creek.
 - Identify properties for retrofit/ purchase/easements, etc.
 - Identify funding resources for buffer efforts (SWCD Tidal Creeks Buffer Program?)

Short-term

- 1) Address fecal coliform levels in the Graham Pond area and areas upstream of Graham Pond.
- 2) Address nitrate levels in the Graham Pond area.

Opportunities for Protection, Restoration, and Education

Bacterial Pollution:

- Public education about impervious surface proliferation
- Efforts to reduce impervious surfaces (in new development, through redevelopment, legislation, other?)
- Efforts to reduce runoff from impervious surfaces (?)
- Public education about pet waste clean up

Nutrient Loading:

- Restore channelized areas to a more natural meandering structure to increase nutrient uptake.

Other:

- Reduce erosion, turbidity, and sedimentation through stream bank stabilization along selected parts of the creek

Completed Protection Efforts

- **Graham Pond area:** The wetland enhancement project was completed in the late 1990's (Mallin et al., 1998).
- **Upper:** A 0.6 acre streamside parcel was purchased by the New Hanover County Tidal Creeks Program for use as a streamside buffer or greenway (UNCW, *Buffer*).
- **Mayfaire:** Approximately 130 acres were preserved as natural areas on the Mayfaire site.

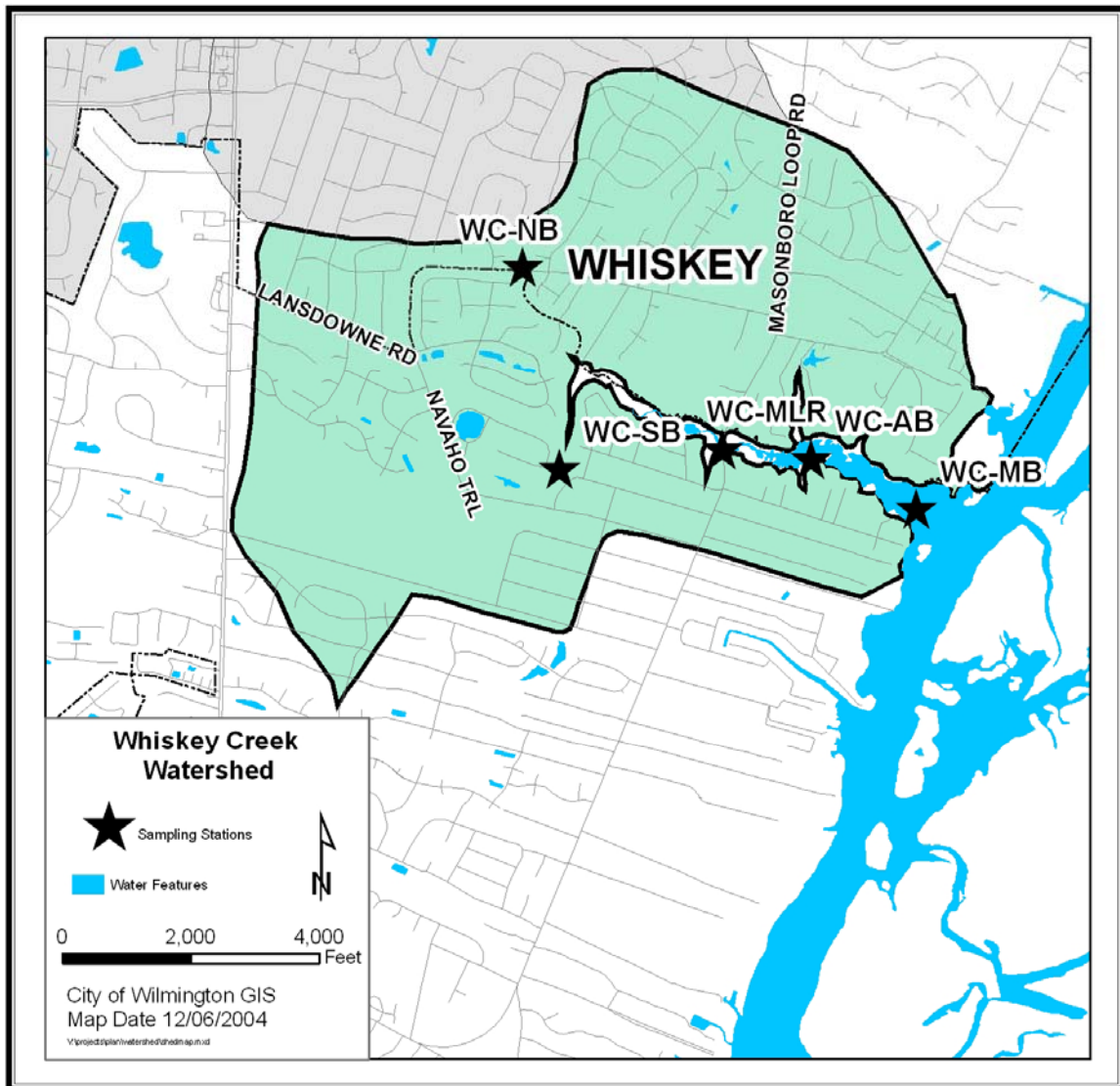
On-going Protection Efforts

- **Johnson Tract:** The New Hanover Tidal Creeks Program has received a Clean Water Management Trust Fund grant to acquire a one-half acre property along Howe Creek. Wetlands on the property will be restored to filter storm water runoff from the Middle Sound Loop Road neighborhood (UNCW, 2005).

4.4 Whiskey Creek

Watershed Description

Whiskey Creek has a **2.1 square-mile** watershed and drains into the Intracoastal Waterway. Whiskey Creek is also sometimes called Purviance Creek.



Stations

WC-MB: Nearest the mouth of the creek, at the marina
WC-AB: Upstream from the mouth, from a private dock
WC-MLR: At the Masonboro Loop Road bridge
WC-SB: South Branch, at Hedgerow Lane
WC-NB: North Branch, at Navajo Trail

Major Watershed Landmarks

Masonboro Loop Road and Masonboro Sound Road.

State Classification

Whiskey Creek is classified as a **High Quality SA** water body (NCDENR, *NC Water Bodies*), which means the creek should be in excellent biological and chemical health. SA waters should support aquatic life, both primary and secondary recreation (activities with frequent or prolonged skin contact), and shellfishing for market purposes. Whiskey Creek is **not supporting** of these intended uses. Whiskey Creek is listed in the 2004 North Carolina Water Quality Assessment and Impaired Waters List (2004 Integrated 305(b) and 303(d) Report) under the Division of Environmental Health's Shellfish Sanitation assessment unit B6 (Masonboro Sound Area). The B6 area is a medium-priority area included in Category 7 of the Impaired Waters List, but an area for which the proper technical conditions to develop a remediation strategy (Total Maximum Daily Load or TMDL) do not currently exist (NCDENR, 2004). The majority of Whiskey Creek is currently **closed to shellfish harvesting** (Sabo, 2004a).

Primary Land Uses

Land use in the Whiskey Creek watershed is dominated by single family residential, which makes up 70% of the total land use. Just over a quarter of the land use is vacant or unknown. Mobile homes, recreation, commercial, multi-family residential, office and institutional, and utilities each contribute slightly to the overall land use. There are no industrial uses.

Figure 4.4.1 Whiskey Creek – Land use in the watershed

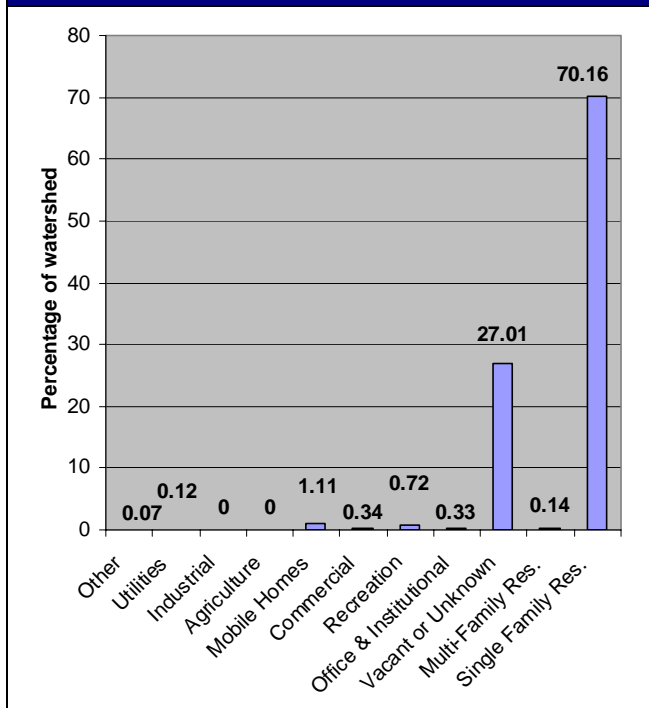
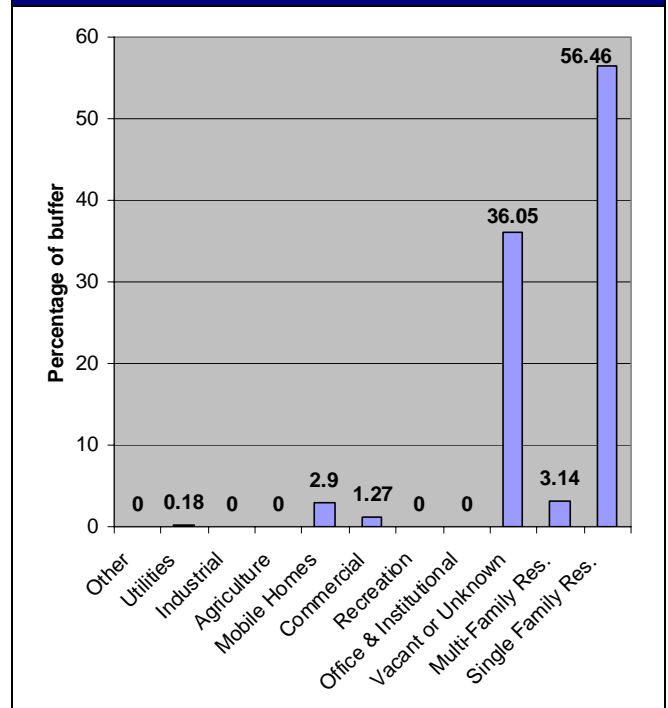


Figure 4.4.2 Whiskey Creek – Land use in the 1000-foot buffer



Major Pollutants and Water Quality Impacts

The Whiskey Creek watershed, at 14% coverage, has the lowest percentage of impervious surface coverage of all the watersheds, both tidal and freshwater. Whiskey Creek, while lower than the rest of the creeks, is still above the 10% threshold for significant impairment and is showing effects of impervious surface related pollution.

Fecal coliform bacteria: Whiskey Creek has had elevated fecal coliform levels since 1999, when consistent sampling in Whiskey Creek first began. Whiskey Creek has been closed to shellfishing since 1971 due to fecal coliform contamination (Sabo, 2004a).

Figure 4.4.3 Whiskey Creek – Fecal coliform

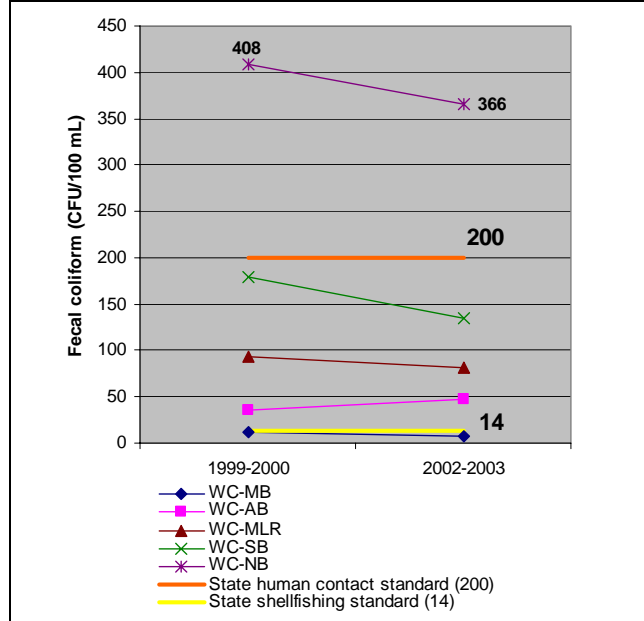


Figure 4.4.4 Whiskey Creek – Nitrate

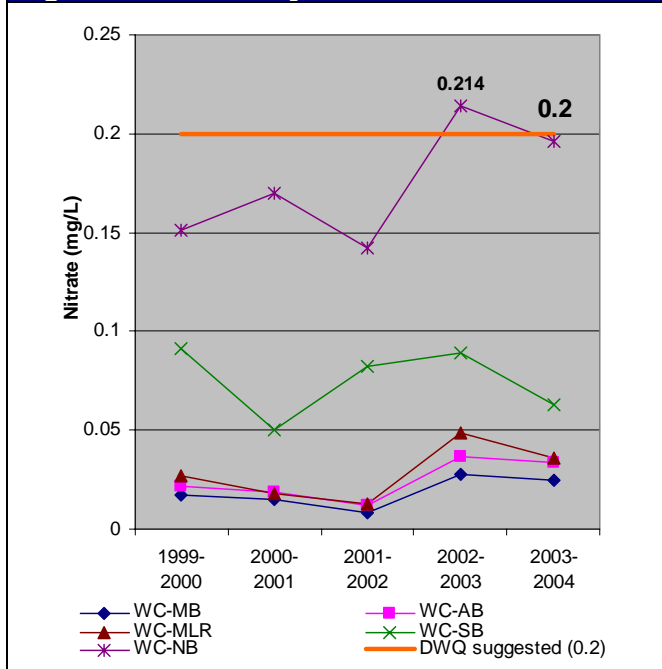
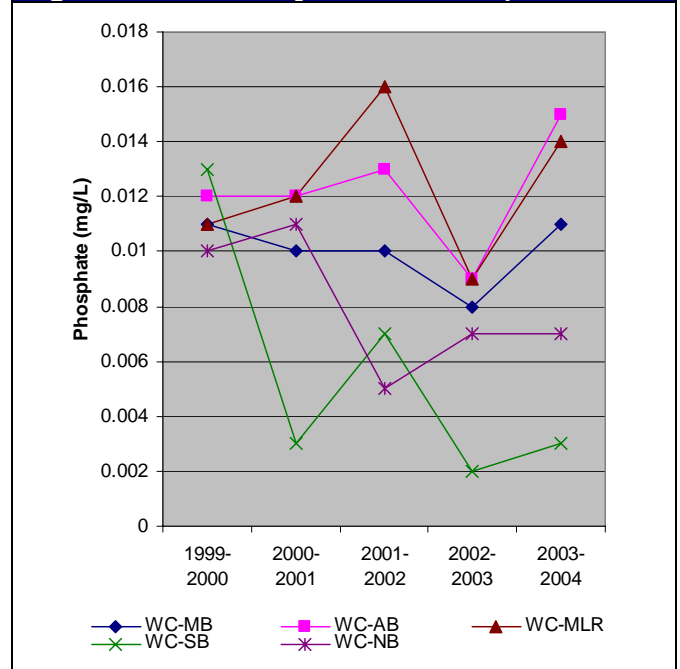
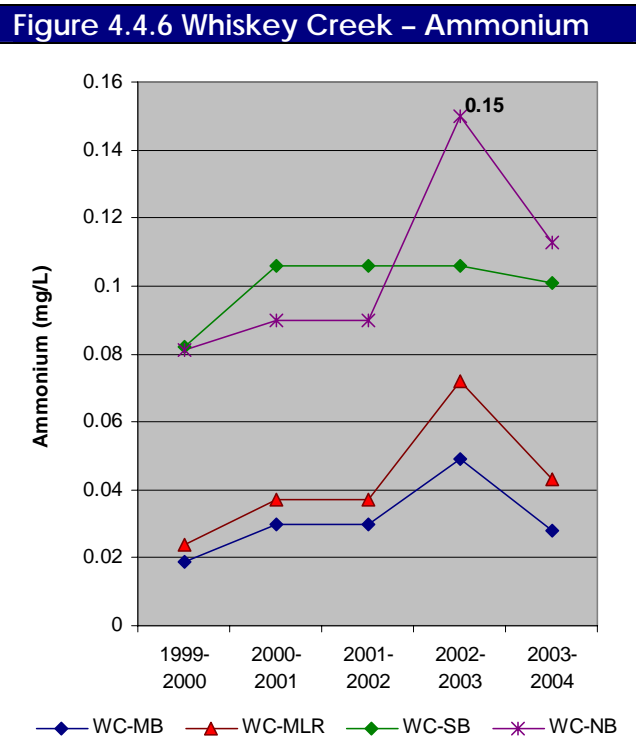


Figure 4.4.5 Whiskey Creek – Phosphate



Nutrients: Nitrate levels were highest up stream, at WC-NB, and ammonium levels at WC-SB and WC-NB (the two uppermost sampling stations) were the highest of any tidal creek levels in 2003. Whiskey Creek had at its mouth the highest phosphate, ammonium, and nitrate levels of all tidal creek mouth sampling stations in Wilmington (Mallin et al, 2004), though no station exceeded the DWQ suggested phosphate level of 0.1 mg/L.



Watershed Goals

Perpetual

Restore and maintain water quality in Whiskey Creek so that the creek is able to support the uses designated by its classification as a High Quality SA waterbody.

- Restore and maintain water quality suitable for primary recreation, such as swimming, and secondary recreation, such as fishing and boating.
- Restore and maintain water quality necessary to sustain a healthy aquatic environment, such as one that would allow shellfishing for market purposes.

Concerns

Fecal coliform
Nutrients

Sources

Urban storm
water runoff
Marinas

Long-term

- 1) Reduce bacterial pollution in Whiskey Creek.
 - Reduce fecal coliform bacteria pollution at all stations to levels consistent with NCDENR state standards for shellfishing (14 colony forming units per 100 milliliters of water).
- 2) Reduce nutrient loading in Whiskey Creek.
 - Reduce nitrate levels at all stations to levels consistent with NCDENR's DWQ suggested maximum (0.2 milligrams per Liter of water).

- Control/ prevent algal blooms.
- 3) Manage all other water quality parameters, including phosphate, ammonium, dissolved oxygen and turbidity, to be maintained at their appropriate levels.

Short-term

- 1) Address fecal coliform levels in the North Branch.
- 2) Address nitrate levels in the North Branch.

Opportunities for Protection, Restoration, and Education

Bacterial Pollution:

- Public education about impervious surface proliferation
- Efforts to reduce impervious surfaces (in new development, through redevelopment, legislation, other?)
- Efforts to reduce runoff from impervious surfaces (?)
- Public education about pet waste clean up

Completed Protection Efforts

- There are no completed protection efforts in the Whiskey Creek watershed.

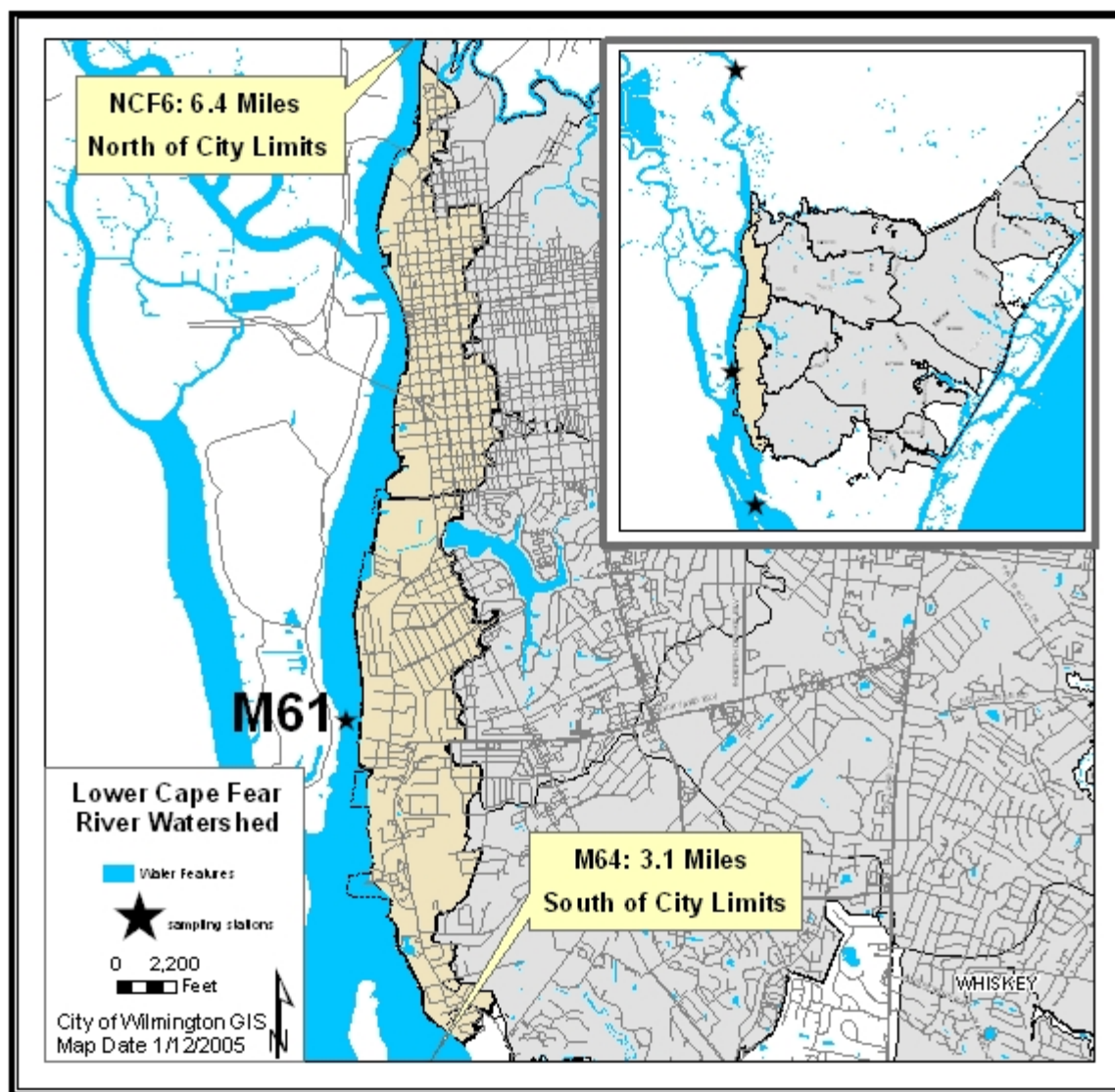
On-going Protection Efforts

- There are no protection efforts underway in the Whiskey Creek watershed.

4.5 Lower Cape Fear River

Watershed Description

The Wilmington portion of the Lower Cape Fear River (LCF) watershed encompasses **3.8 square miles**. This section of the river is part of the NCDENR Division of Water Quality's Cape Fear River Subbasin 17, which includes the lower reaches of the Cape Fear River. Subbasin 17 includes the Brunswick River and Town, Wilmington, and Southport (NCDENR *Basinwide* 2004).



Stations

NCF6: 6.4 miles north of Wilmington, at the GE dock
M61: Channel marker 61 at NC State Port in downtown Wilmington
M54: Channel marker 54, 5 kilometers south of Wilmington

Major Watershed Landmarks

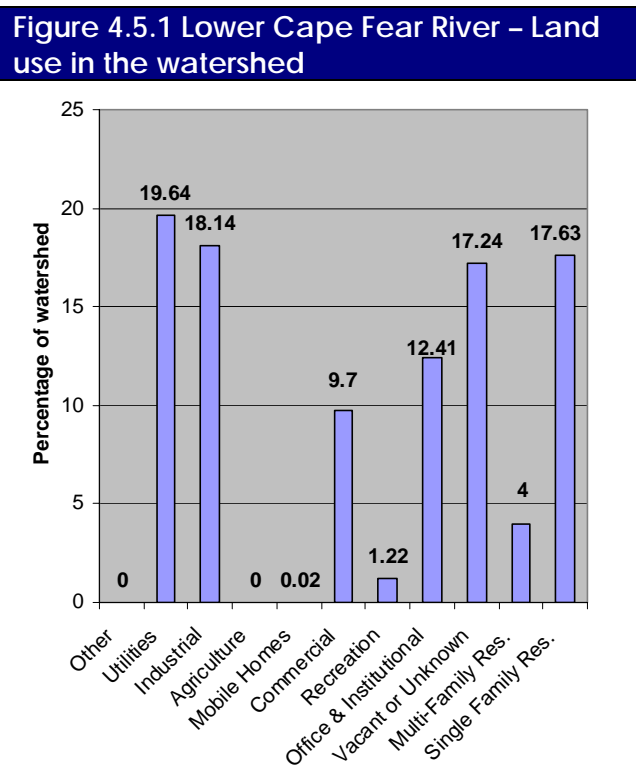
Downtown Wilmington, the Wilmington docks/ State Port, River Road.

State Classification

The Lower Cape Fear River (LCF) is classified **SC**, which means the river should be able to support aquatic life (including shellfish for non-market purposes), wildlife, and secondary recreation. Currently, the Lower Cape Fear River is **not supporting** of these intended uses. The Lower Cape Fear River is listed in the 2004 North Carolina Water Quality Assessment and Impaired Waters List (2004 Integrated 305(b) and 303(d) Report) under the Division of Environmental Health's Shellfish Sanitation assessment unit B10. The B10 area is included in Category 5 of the Impaired Waters List, which means it is a high-priority clean up area that has been contaminated by one or more pollutants (NCDENR, 2004).

Primary Land Uses

Utilities account for the most prevalent land use in the Lower Cape Fear River watershed, with the bulk of the utilities uses existing in the lower portion of the watershed. Industrial uses are the second largest land use. Single family residences and vacant lands make up the majority of the remaining land uses, while office and institutional and commercial uses are also present.



Major Pollutants and Water Quality Impacts

The water quality information for the Lower Cape Fear River watershed comes from the Lower Cape Fear River Program. Three sampling stations were included in this report to show how water quality in the Cape Fear River changes from north of Wilmington to south of Wilmington. The Wilmington portion of the Lower Cape Fear watershed is 43% covered with impervious surfaces. While this is the highest percentage of all watershed coverages, the majority of the watershed lies outside the City Limits, therefore the impervious surface coverage percentage may not be a reliable indicator of causes or level of impairment.

Mercury: Fish tissue samples from the Lower Cape Fear River Basin in 1998 contained mercury at levels higher than the Environmental Protection Agency's acceptable limits (NCDENR, 1999).

Fecal coliform bacteria: Fecal coliform levels spiked in 1998-1999, elevating stations NCF6 and M61 to levels above the state human contact standard of 200 colony forming units/100 mL. The station downstream of Wilmington, however, experienced no spike and remained well below the human contact standard. There was another spike in 2000-2001, with only the two down river stations showing elevated levels, but all stations remained below the human contact standard. Levels have generally declined since 2000-2001, but all stations remain above the shellfishing standard of 14 colony forming units/100 mL.

Figure 4.5.2 Lower Cape Fear River – Fecal coliform

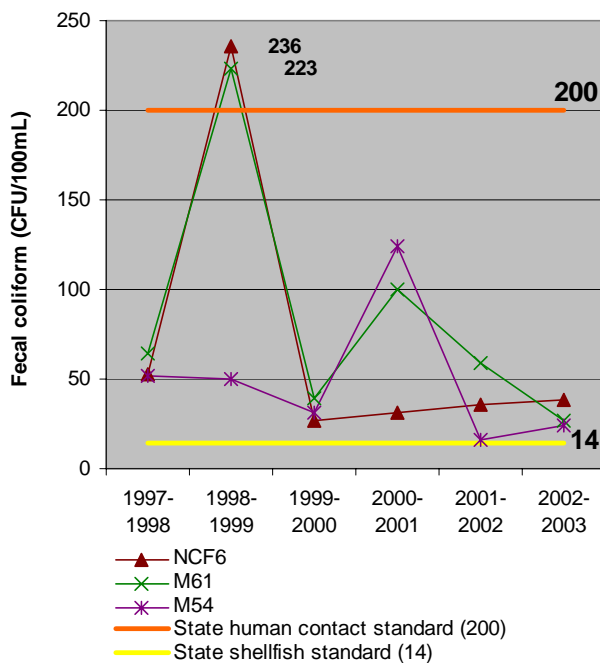
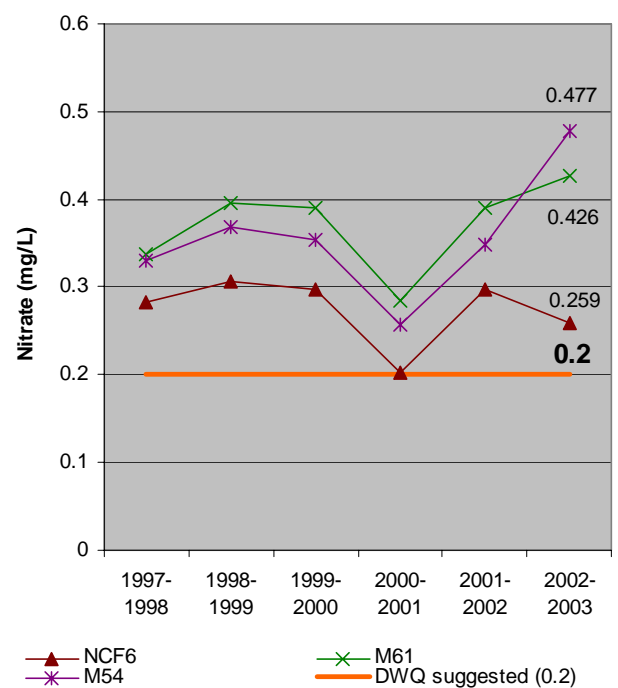


Figure 4.5.3 Lower Cape Fear River - Nitrate

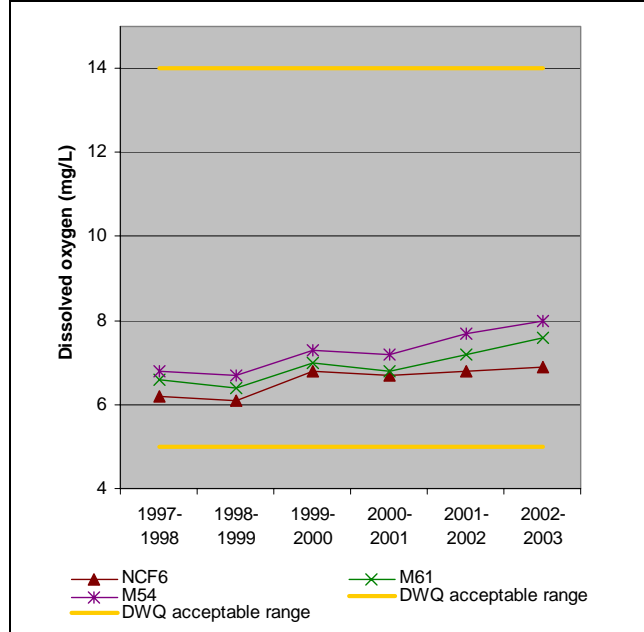


Nitrate: Nitrate levels at all three stations have consistently exceeded the DWQ suggested level, though station NCF6 reached a low of .202 mg/L in 2000-2001. M61 and M54, the stations adjacent to and down river of Wilmington, have shown consistently higher nitrate levels than NCF6, the station upriver of the City. Additionally, while nitrate levels at NCF6 have fallen since 2000, levels at the two down river stations have increased.

Oxygen limitation: All three of the Lower Cape Fear River sampling stations showed somewhat low, though still acceptable, levels of dissolved oxygen. Samples taken specifically at the Wilmington Docks area, the most heavily impacted site in the subbasin, showed evidence of low dissolved oxygen levels (NCDENR, *Basinwide* 1999). Samples

taken at the the Southside wastewater treatment plant outfall area also showed low dissolved oxygen (NCDENR, *Basinwide* 1999).

Figure 4.5.4 Lower Cape Fear River – Dissolved oxygen



Other concerns:

- **Fish kill:** There was a fish kill of approximately 450 fish in September 2003 (Mallin et al, 2004). No reason was given for the kill by the UNCW Center for Marine Science.
- **Estuarine Biotic Index:** The Wilmington Docks area has the lowest Estuarine Biotic Index (EBI) rating in the subbasin (1.24) and shows evidence of toxic aquatic impacts (NCDENR, 1999). The Southside wastewater treatment plant outfall area has an EBI of "Elevated Impact," indicating a relatively stressed aquatic community (NCDENR, 1999).
- **Point Source Discharges:** There are seven point source dischargers within the Wilmington City limits:
 - Amerada Hess Corp (permit #NC0066711): Operates an oil and water separator and a two-stage lagoon. Permitted to discharge stormwater, boiler blowdown water, truck wash waters, rack wash waters, hydrostatic test waters, and floor cleaning wash waters.
 - CTI (permit #NC0082970): Permitted to discharge stormwater at 3 outfall sites.
 - Koch Petroleum Group/ Flint Hills Resources (permit #NC0076732): Operates an oil and water separator. Permitted to discharge stormwater, tank bottom water, hydrostatic test water and groundwater.
 - JLM Terminals (permit #NC0028568): Permitted to discharge stormwater.
 - Paktank Vopak Terminal (permit #NC0073172): Permitted to discharge boiler blowdown and stormwater.
 - Northside Waste Water Treatment Plant (permit #NC0023965): Permitted to discharge 8 million gallons per day of treated waste water.

- Southside Waste Water Treatment Plant (permit #NC0023973): Permitted to discharge 12 million gallons per day of treated waste water.

Watershed Goals

Perpetual

Restore and maintain water quality in the Lower Cape Fear River so that the river is able to support the uses designated by its classification as a SC waterbody.

- Restore and maintain water quality suitable for secondary recreation, such as boating, fishing, and infrequent swimming.
- Restore and maintain water quality necessary to sustain a healthy aquatic environment.

Concerns

Mercury
Fecal coliform
Nutrients
Dissolved oxygen

Sources

Urban storm water
runoff

Long-term

- 1) Reduce bacterial pollution in the Lower Cape Fear River.
 - Reduce fecal coliform bacteria pollution at all stations to levels consistent with NCDENR state standards for shellfishing (14 colony forming units per 100 milliliters of water).
- 2) Reduce nutrient loading in the Lower Cape Fear River.
 - Reduce nitrate at all stations to levels consistent with NCDENR's DWQ suggested maximum (0.2 milligrams per Liter of water).
 - Control nitrate entering the river from the City.
 - Determine sources of nitrate.
- 3) Maintain dissolved oxygen at appropriate levels.
- 4) Manage all other water quality parameters, including phosphate, ammonium, dissolved oxygen and turbidity, to be maintained at their appropriate levels.

Short-term

- 1) Address fecal coliform levels.
- 2) Address nitrate levels.
- 3) Address dissolved oxygen levels, specifically in the Wilmington Docks and the Southside Waste Water Treatment Plant areas.

Opportunities for Protection, Restoration, and Education

Bacterial Pollution:

- Public education about impervious surface proliferation
- Efforts to reduce impervious surfaces (in new development, through redevelopment, legislation, other?)
- Efforts to reduce runoff from impervious surfaces (?)
- Public education about pet waste clean up

Completed Protection Efforts

- There are no completed protection efforts in the Lower Cape Fear watershed.

On-going Protection Efforts

- There are no current protection efforts underway in the Lower Cape Fear watershed.

5. Water Quality in Wilmington's Freshwater Creeks

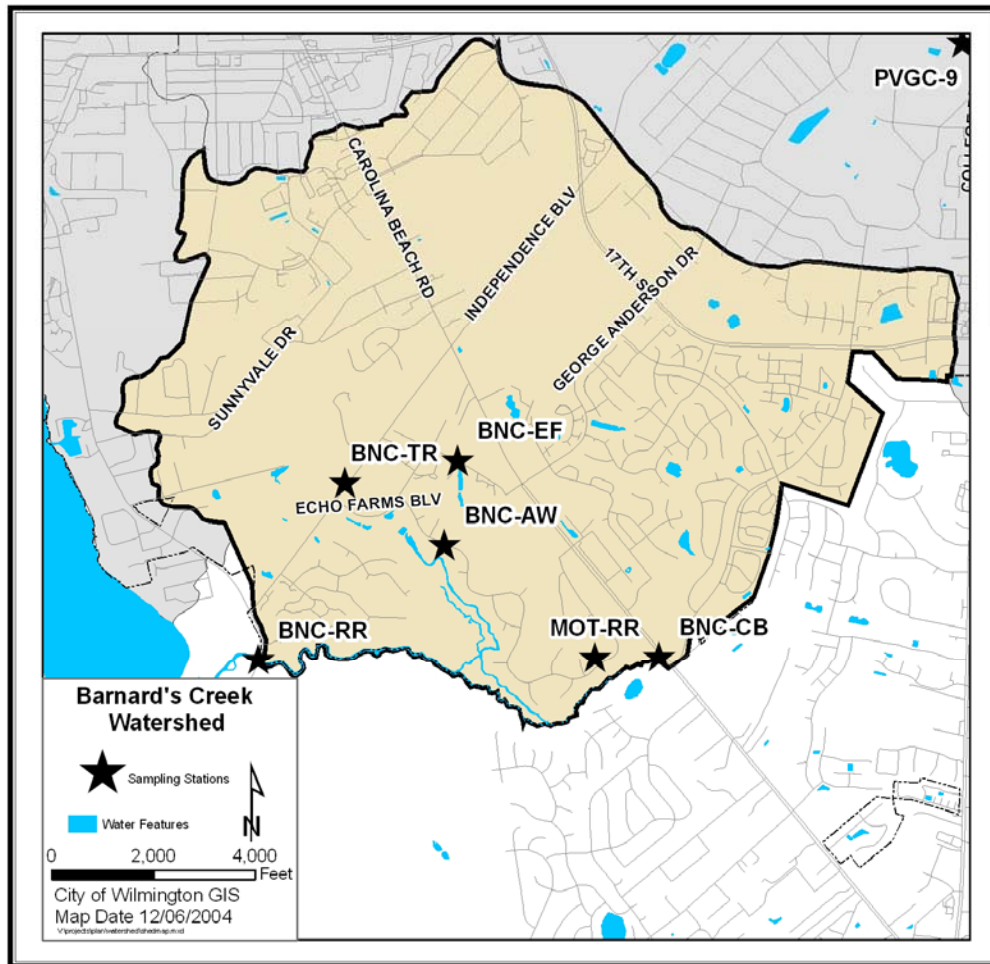
Table 5.1 Freshwater Creek Summary

Name	Status	Class	Notes
Barnard's Creek	Not Rated	C, Sw	NCDENR will not test this creek because of its small size and high salinity. Receives discharge from one NPDES permitted facility.
Burnt Mill Creek	Impaired	C, Sw	Receives discharge from one NPDES permitted facility.
Greenfield Creek	Impaired	C, Sw	
Smith Creek	Not Rated	C, Sw	NCDENR will not test this creek because of its small size.

5.1 Barnard's Creek

Watershed Description

The Barnard's Creek watershed encompasses **4.6 square miles** and is the fifth largest watershed in Wilmington. Barnard's Creek flows into the Lower Cape Fear River. NCDENR's Division of Water Quality (DWQ) has not sampled Barnard's creek, considering it too small and too salty to be monitored. Barnard's Creek has not been addressed in basinwide planning efforts and will continue to be left out of future water quality sampling by NCDENR's DWQ (McNutt, March 22, 2004). Barnard's Creek has been sampled by the UNCW Center for Marine Science since 1997.



Stations

BNC-TR: At Titanium Road

BNC-CB: Near Carolina Beach Road

BNC-RR: At River Road

BNC-EF: Input to wet detention pond at Echo Farms Golf Course (sampled from 1997 to 2001)

BNC-AW: Output of wet detention pond at Echo Farms Golf Course (sampled from 1997 to 2001)

Major Watershed Landmarks

Carolina Beach Road, Independence Boulevard.

State Classification

Barnard's Creek is classified as a class **C**, **Sw** water body, which means the creek should be able to support secondary recreation and wildlife and aquatic life propagation. There are no restrictions on the type of development uses in class C watersheds. The SW (swamp waters) designation indicates that the creek is topographically situated so as to have very low velocities and other characteristics different from creeks located in topographically steeper areas. Since NCDENR does not sample Barnard's Creek due to its swampy qualities, Barnard's Creek has not been officially declared as either meeting or failing to meet its use designation so there is currently **no official use support rating**.

Primary Land Uses

Vacant land or land for which the use is unknown comprises the majority of land in the Barnard's Creek watershed. Single family residential is the only other prevalent use, constituting a quarter of the land use. Recreation, office and institutional and multi-family residential uses each account for a small portion of the total land use. Also present in smaller amounts are commercial, agricultural, industrial, mobile home, and utilities uses.

Figure 5.1.1 Barnard's Creek – Land use in the watershed

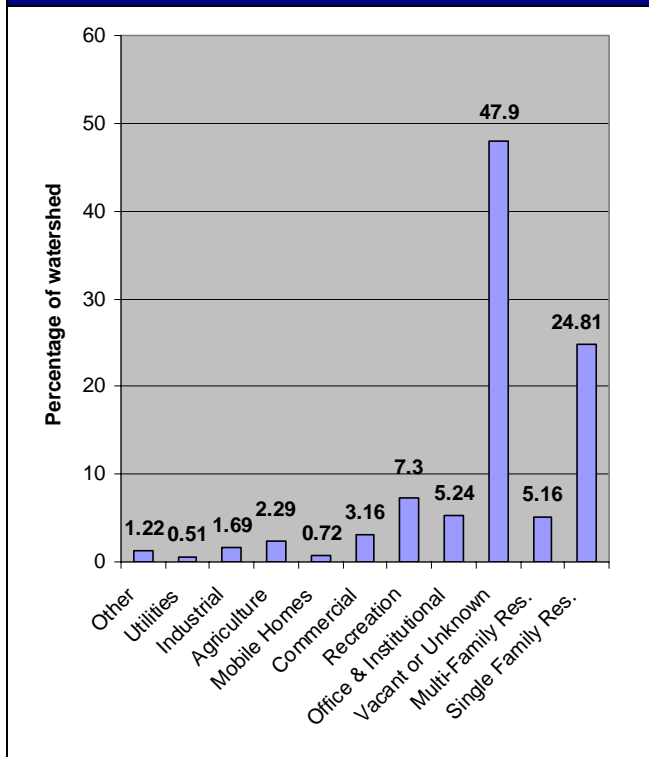
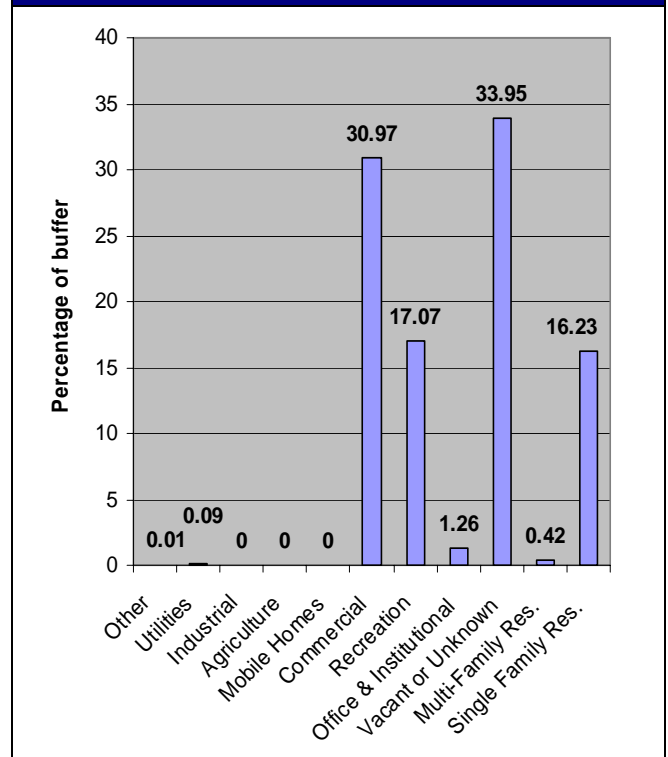


Figure 5.1.2 Barnard's Creek – Land use in the 1000-foot buffer



Major Pollutants and Water Quality Impacts

At 17%, the Barnard's Creek watershed has the lowest impervious surface coverage amount of all the freshwater creeks.

Turbidity: Turbidity can be caused by sediments washing into the creek from increased erosion or from land-disturbing activities, such as building construction, or from large

volume discharges that stir up sediments from the creek bed, making the water muddy. Turbidity increases the particulate matter in the water, making it harder for aquatic creatures to “breathe.” Turbid water also keeps sunlight from penetrating very far into the creek, hindering the photosynthetic capabilities of underwater plants and possibly affecting creek temperature. Turbidity in Barnard’s Creek has increased in the last several years, especially at BNC-TR. BNC-TR, the Titanium Road station, had been considered a background site and was used to comparatively evaluate impacts on water quality in the creek, as the station drained mostly wooded areas. Over the last couple of years, however, construction and increased activity on Titanium Road near this station have dramatically affected water quality at this site, and it no longer serves as a background sampling site.

Figure 5.1.3 Barnard’s Creek – Turbidity at selected stations

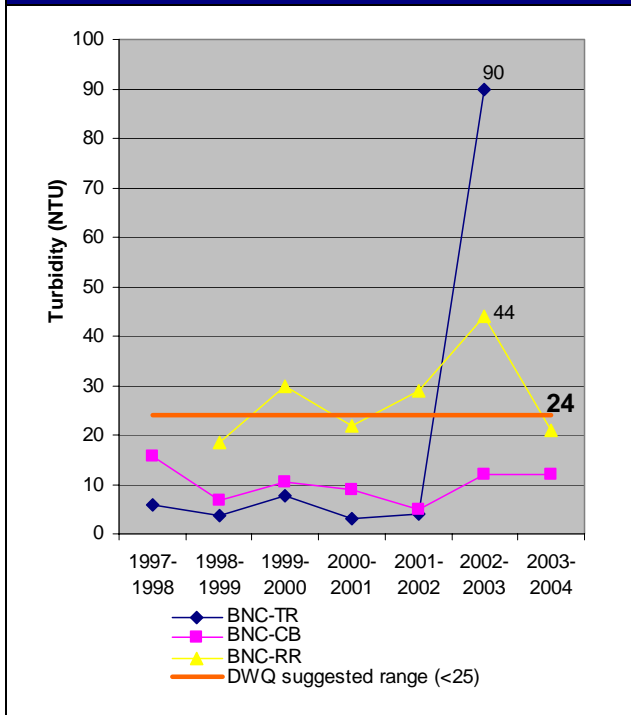
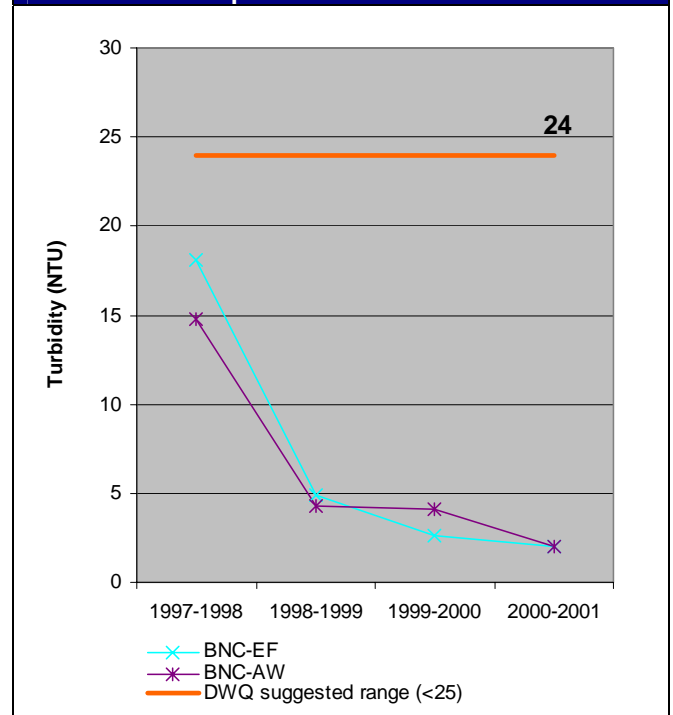


Figure 5.1.4 Barnard’s Creek – Turbidity at wet detention pond



Fecal coliform: Sampling in 2002-2003 at stations near Titanium Road and Carolina Beach Road exceeded the state fecal coliform standard in 50% and 75% of sampling events, respectively (Mallin et al., 2004). This may be contributed to the increased construction activity along these roads. Fecal coliform levels in the wet detention pond at Echo Farms Golf Course increased significantly in the years following the construction of the pond in the late 1990s.

Dissolved Oxygen: Dissolved oxygen has decreased at all three in-stream monitoring stations since 2001-2002 (Mallin et al., 2004). Dissolved Oxygen at the Titanium Road site (BNC-TR) has been steadily decreasing over this time frame and in 2002-2003 dropped below the minimum dissolved oxygen level required to support aquatic life. Dissolved oxygen at the wet detention pond remained consistent, though fairly low, during its five-year sampling period.

Figure 5.1.5 Barnard's Creek – Fecal coliform at selected stations

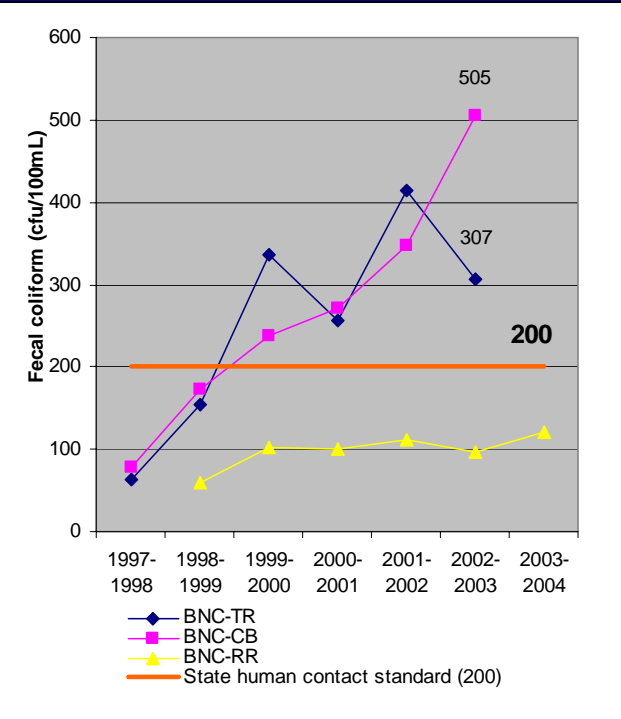


Figure 5.1.6 Barnard's Creek – Fecal coliform at wet detention pond

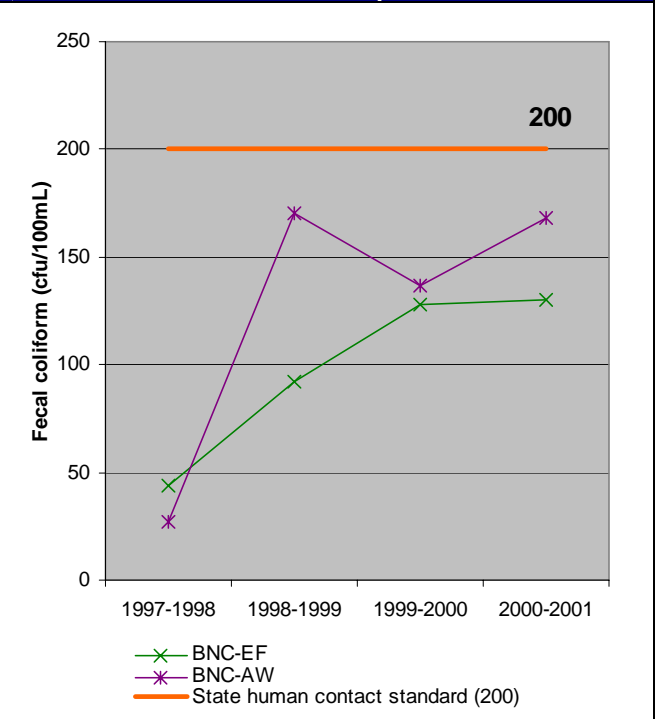


Figure 5.1.7 Barnard's Creek – Dissolved oxygen at selected stations

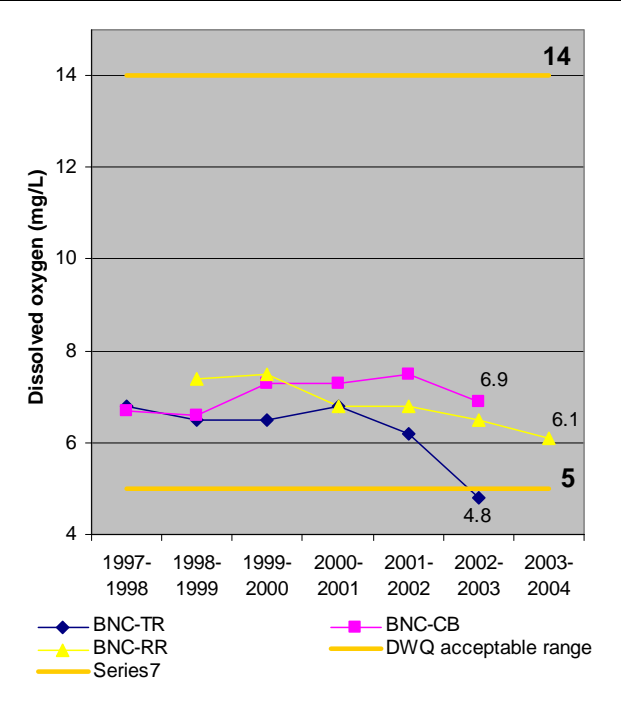
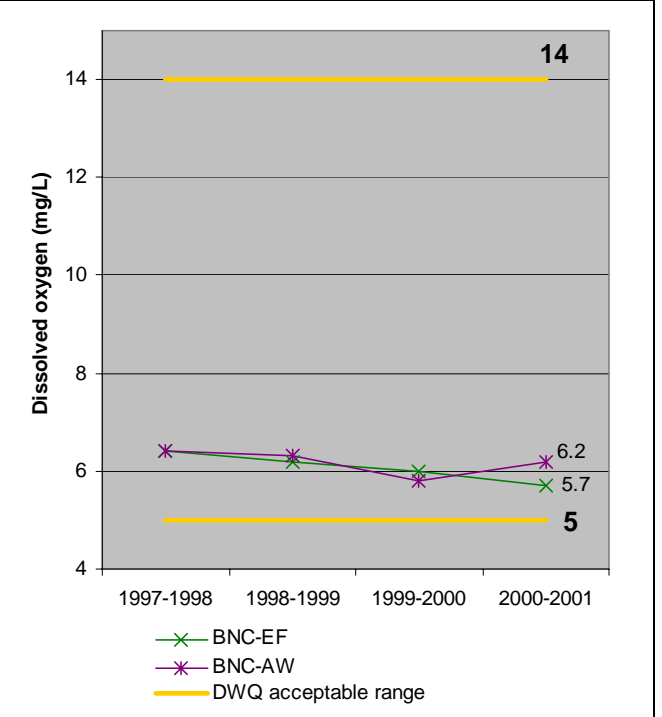


Figure 5.1.8 Barnard's Creek – Dissolved oxygen at wet detention pond



Other Concerns:

- Point Source Dischargers

- AAF-McQuay (Permit #NC0083658): Permitted to discharge treated groundwater into Barnard's Creek.

Watershed Goals

Perpetual

Restore and maintain water quality in Barnard's Creek so that the creek is able to support the uses designated by its classification as a C, Sw waterbody.

- Restore and maintain water quality suitable for secondary recreation.
- Restore and maintain water quality necessary to sustain a healthy aquatic environment.

Long-term

- 1) Reduce turbidity in Barnard's Creek.
 - Implement/enforce tighter construction site erosion standards/practices
- 2) Reduce bacterial pollution in the Lower Cape Fear River.
 - Reduce fecal coliform bacteria pollution at all stations to levels consistent with NCDENR state standards for human contact (200 colony forming units per 100 milliliters of water).
- 3) Maintain dissolved oxygen at appropriate levels.
- 4) Manage all other water quality parameters, including phosphate, ammonium, dissolved oxygen and turbidity, to be maintained at their appropriate levels.

Short-term

- 1) Identify sources of sediments entering Barnard's Creek and address those existing conditions.
- 2) Address dissolved oxygen levels, specifically in the Wilmington Docks and the Southside Waste Water Treatment Plant areas.

Opportunities for Protection, Restoration, and Education

Bacterial Pollution:

- Public education about impervious surface proliferation
- Efforts to reduce impervious surfaces (in new development, through redevelopment, legislation, other?)
- Efforts to reduce runoff from impervious surfaces (?)
- Public education about pet waste clean up

Completed Protection Efforts

- There are no completed protection efforts in Barnard's Creek watershed.

On-going Protection Efforts

- There are no protection efforts currently underway in Barnard's Creek watershed.

Concerns

Turbidity
Fecal coliform
Low Dissolved
Oxygen

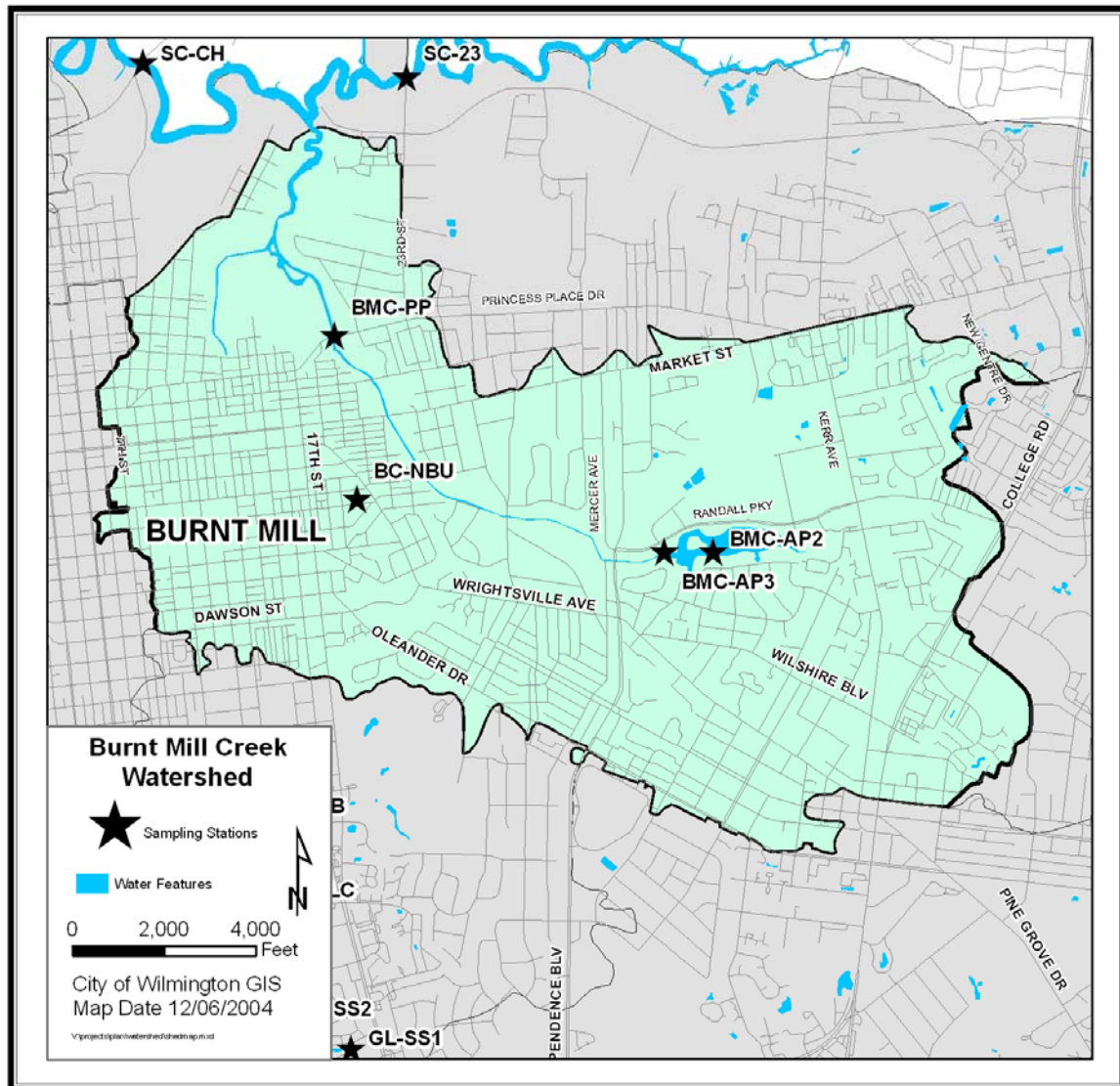
Sources

Urban storm
water runoff
Point source
discharges

5.2 Burnt Mill Creek

Watershed Description

Burnt Mill Creek is Wilmington's third largest watershed, encompassing **6.7 square miles**. Burnt Mill Creek flows into the Lower Cape Fear River.



Stations

BMC-AP1: Just upstream of Ann McCrary Pond on Randall Parkway
BMC-AP2: Midway down Ann McCrary Pond (sampled 1997 to 2001)
BMC-AP3: 40 meters below Ann McCrary outfall
BMC-PP: Princess Place bridge

Major Watershed Landmarks

Randall Parkway, Ann McCrary Pond, Carolina Beach Road.

State Classification

Burnt Mill Creek is also classified as a class **C**, **Sw** water body, which means the creek should be able to support secondary recreation and wildlife and aquatic life propagation, there are no development restrictions, and it has relatively low velocities. Burnt Mill Creek is **not supporting** of these uses. Burnt Mill Creek is listed on the 2004 North Carolina Water Quality Assessment and Impaired Waters List (2004 Integrated 305(b) and 303(d) Report) under category 6, which means it is a high priority.

Primary Land Uses

Single family residential represents the most prevalent land use in the Burnt Mill Creek watershed. Vacant lands or land for which the use is unknown account for the second most prevalent use at 18%. Commercial uses and multi-family residential each account for about 12% of the land use. Office and institutional represents approximately 11%, while recreation accounts for approximately 6%. Industrial, utilities, mobile homes, and agriculture are also present at low percentages.

Figure 5.2.1 Burnt Mill Creek – Land use in the watershed

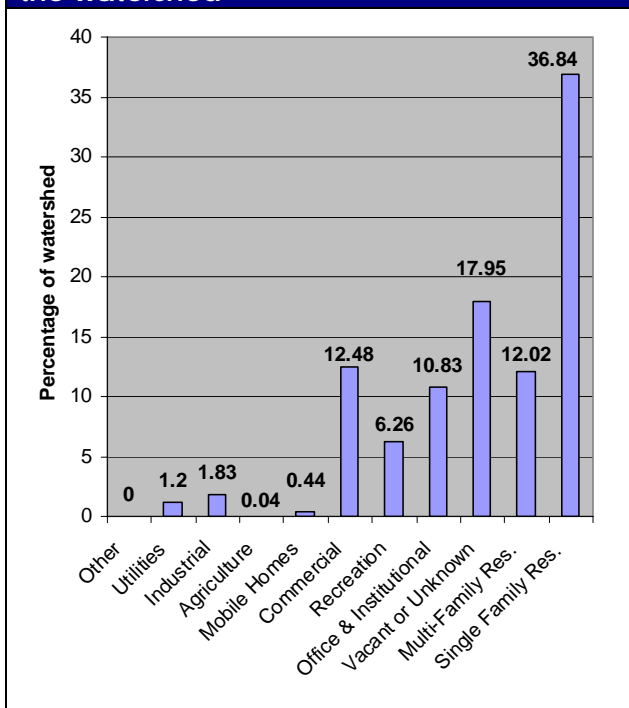
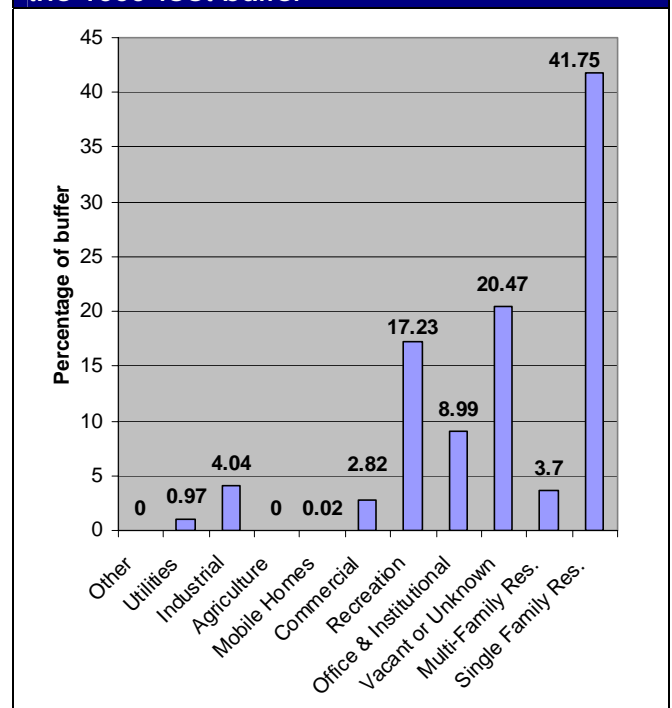


Figure 5.2.2 Burnt Mill Creek – Land use in the 1000-foot buffer



Major Pollutants and Water Quality Impacts

The Burnt Mill Creek watershed is 36% covered with impervious surfaces, second only to the Greenfield Lake watershed. Burnt Mill Creek also has the highest fecal coliform levels of all the freshwater creeks in Wilmington.

Fecal coliform: In 2002-2003, fecal coliform was extremely high at the sampling station upstream of Ann McCrary Pond (Mallin et al. 2004). Fecal coliform levels dropped at the sampling station below the pond, though they remained above the state standard for human contact, and rose again significantly farther downstream at the third sampling

station near Princess Place (Mallin et al. 2004). Fecal coliform has always been high at the upstream and downstream stations due to pet waste and urban storm water runoff (Mallin et al. 1998 - 2004).

Dissolved Oxygen: Though no stations have fallen below the absolute minimum in the last several years, BMC-AP1 and BMC-PP maintain fairly low dissolved oxygen levels. Dissolved oxygen increases from upstream of Ann McCrary Pond (BMC-AP1) to the station below the pond outfall (BMC-AP3) but decreases to very low levels again at Princess Place. This indicates that the pond helps restore more desirable oxygen levels.

Figure 5.2.3 Burnt Mill Creek – Fecal coliform at all stations

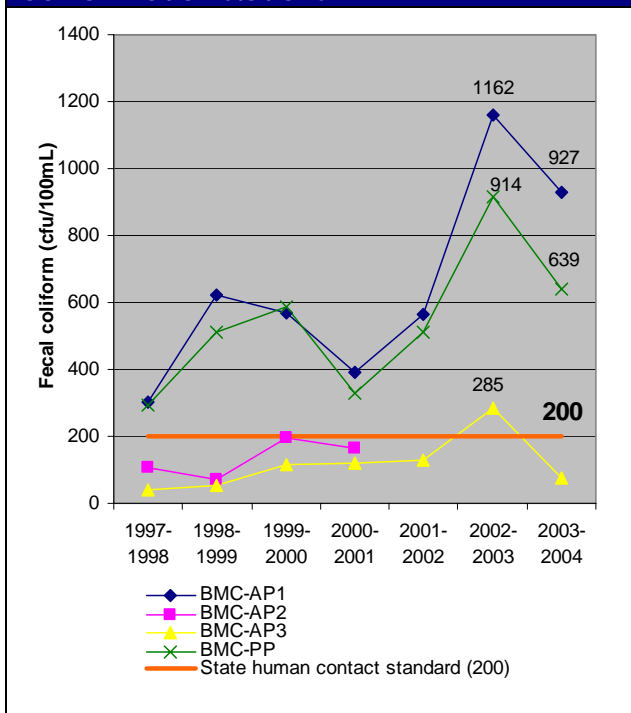
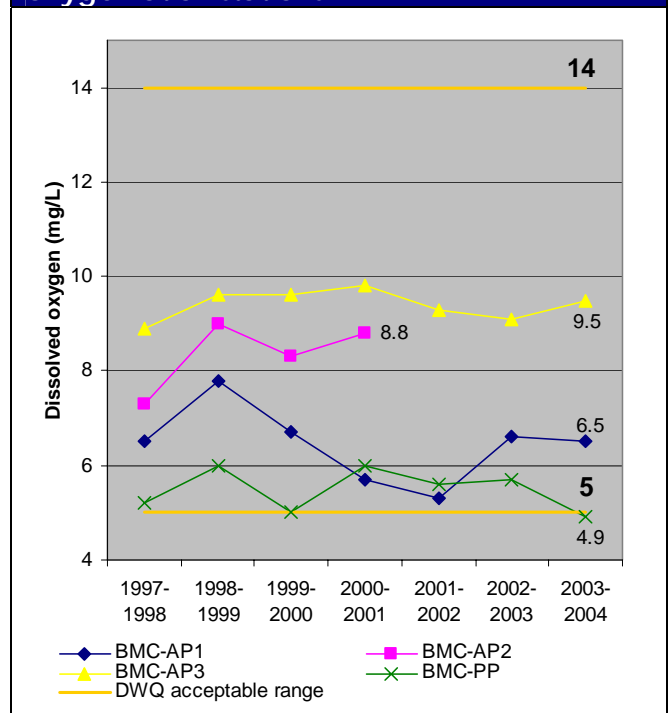


Figure 5.2.4 Burnt Mill Creek – Dissolved oxygen at all stations



Other Concerns:

- The ability of Ann McCrary Pond to decrease turbidity, fecal coliform, and nutrient loading is impaired by a suburban drainage system that inputs nutrients into the pond and by the proliferation of significant aquatic plant life (Mallin et al., 2004).
- Ann McCrary Pond hosts the North Carolina threatened plant species *Lilaeopsis carolinensis* (Mallin et al., 2004).
- **Point Source Dischargers:**
 - International Paper (permit #NC0081507): Permitted to discharge to Burnt Mill Creek.

Watershed Goals

Perpetual

Restore and maintain water quality in Burnt Mill Creek so that the creek is able to support the uses designated by its classification as a C, Sw waterbody.

- Restore and maintain water quality suitable for secondary recreation.
- Restore and maintain water quality necessary to sustain a healthy aquatic environment.

Concerns

Fecal coliform
Low Dissolved
Oxygen

Sources

Urban storm
water runoff

Long-term

- 1) Reduce bacterial pollution in the Lower Cape Fear River.
 - Reduce fecal coliform bacteria pollution at all stations to levels consistent with NCDENR state standards for human contact (200 colony forming units per 100 milliliters of water).
- 3) Maintain dissolved oxygen at appropriate levels.
- 4) Maintain all other water quality parameters, including phosphate, ammonium, and turbidity at their appropriate levels.

Short-term

- 1) Address fecal coliform levels at all stations.
- 2) Address particularly low dissolved oxygen levels at extreme upstream and extreme downstream stations.

Opportunities for Protection, Restoration, and Education

Bacterial Pollution:

- Public education about impervious surface proliferation
- Efforts to reduce impervious surfaces (in new development, through redevelopment, legislation, other?)
- Efforts to reduce runoff from impervious surfaces (?)
- Public education about pet waste clean up

Completed Protection Efforts

- The NCDENR Division of Water Quality's Wetland Restoration Program, in partnership with the Cape Fear River Watch and the City of Wilmington Storm Water Services, installed a storm water wetland at the corner of Kerr Avenue and Fountain Drive in 2001 (Cape Fear River Watch, 2005).
- One quarter of an acre of wetlands in Wallace Park was restored through a retrofit of an existing drainage system as part of the Market Street Drainage Relief Project.

On-going Protection Efforts

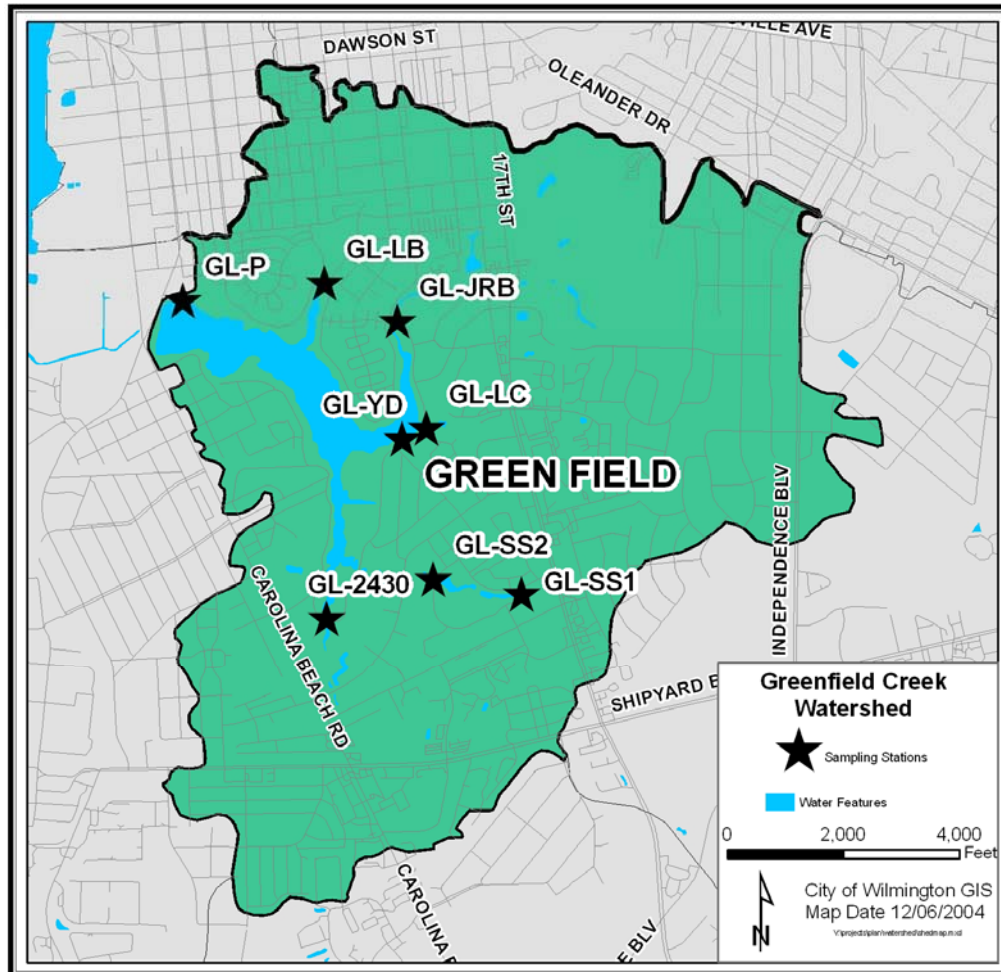
- The Ecosystem Enhancement Program of the New Hanover County Watershed Planning Initiative (formerly known as the NHC Wetlands Restoration Project) is restoring sections of Burnt Mill Creek along the Mineral Springs Branch at Forest Hills. They are also installing storm water Best Management Practices (BMP) retrofits.

- A 319 grant was made available for Burnt Mill Creek through the State's Watershed Education for Communities and Government Officials. The project team for the grant is in the process of identifying 4-6 locations in the Burnt Mill Creek watershed, including Ann McCrary Pond, where the effectiveness of storm water BMPs can be demonstrated.

5.3 Greenfield Creek

Watershed Description

Encompassing **4 square miles**, Greenfield Creek (also known as Greenfield Lake watershed) is Wilmington's 7th largest watershed. The lake was created in 1750 by damming Greenfield Creek. There is a large wet detention pond along the Silver Stream branch of Greenfield Lake. Approximately 43% of the pond's drainage area is covered with impervious surfaces (NCDENR Basinwide 2004).



Stations

GL-SS1: Input to wet detention pond on Silver Stream Branch
GL-SS2: Output from wet detention pond on Silver Stream Branch
GL-JRB: Near midpoint of Jumping Run Branch
GL-LB: Creek at Lake Branch Drive
GL-LC: Creek beside Lakeshore Commons
GL-2340: In-lake upstream station nearest Carolina Beach Road
GL-YD: In-lake station downstream of Lakeshore Commons
GL-P: Greenfield Park

Major Watershed Landmarks

Greenfield Lake, Carolina Beach Road, 17th Street.

State Classification

Greenfield Lake is classified as a class **C, SW** water body. This classification means the lake should be able to support secondary recreation and wildlife and aquatic life propagation, there are no development restrictions, and it has relatively low velocities. Greenfield Lake is **not supporting** of these uses. Greenfield Lake is listed on the 2004 North Carolina Water Quality Assessment and Impaired Waters List (2004 Integrated 305(b) and 303(d) Report) under category 5, which means it is a high priority water body for which a TMDL (Total Maximum Daily Load) is required. Greenfield Lake is listed as impaired due to nuisance levels of aquatic vegetation.

Primary Land Uses

Nearly half (47%) of the Greenfield Creek watershed is vacant land or lands for which the use is unknown. Single family residential is the next most prevalent land use, accounting for nearly a quarter (24%) of land use in the watershed. Recreation, multi-family residential, and office and institutional make up the bulk of the remaining quarter of land uses with 11%, 7% and 7%, respectively. A small amount of commercial, utilities, industrial, and mobile home uses are also present.

Figure 5.3.1 Greenfield Creek – Land use in the watershed

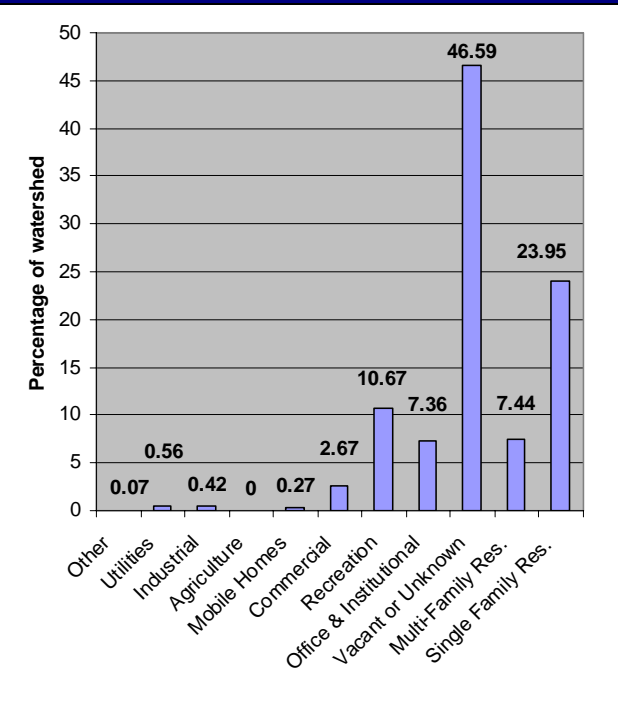
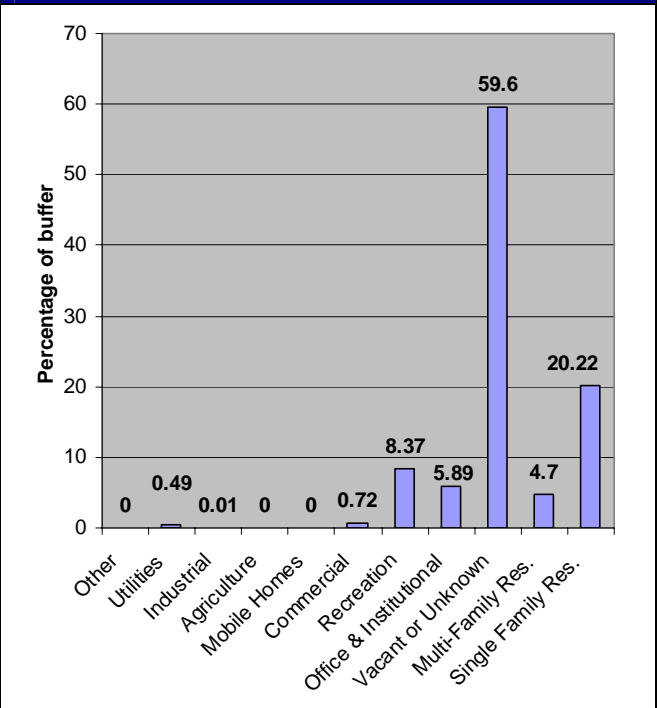


Figure 5.3.2 Greenfield Creek – Land use in the 1000-foot buffer



Major Pollutants and Water Quality Impacts

At 36%, Greenfield Lake ties with Burnt Mill Creek for highest impervious surface coverage. While fecal coliform is not as high a concern in Greenfield Lake as in other water bodies, nutrients, presumably from impervious surface runoff, are posing a significant problem.

Aquatic weeds: Aquatic weeds have historically been a problem in Greenfield Lake, causing low dissolved oxygen levels and a hindrance to recreational use of the lake. Along with nutrients, aquatic weeds are the reason for the Lake's impaired status listing. Water meal, Duckweed, and Brazilian elodea are the weeds considered problematic (NCDENR 2004).

Nutrients: Nutrient loading has been a recurrent problem in Greenfield Lake due to the large amount of runoff the lake receives. Phytoplankton blooms - usually green or blue algae - occur at problematic levels primarily in the spring and summer. Nutrients and phytoplankton blooms seemed to be less of a problem in 2002-2003 than in previous years (Mallin et al., 2004). Nutrient loading also contributes to the propagation of aquatic weeds (NCDENR 2004).

Low dissolved oxygen: Three of Greenfield Lake's tributaries, Jumping Run Branch, the creek at Lake Branch Drive, and the creek beside Lakeshore Commons, were found to suffer from extreme hypoxia in 2002-2003. Three in-lake stations also showed low dissolved oxygen levels. Low dissolved oxygen is one of the two parameters considered by the Center for Marine Science to have impaired the lake in 2002-2003 (Mallin et al. 2004).

Figure 5.3.3 Greenfield Creek – Nitrate at all stations

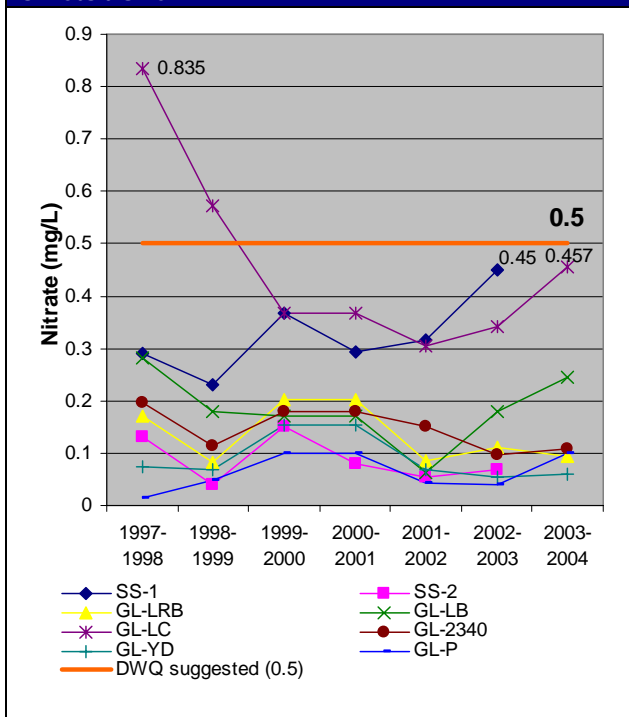
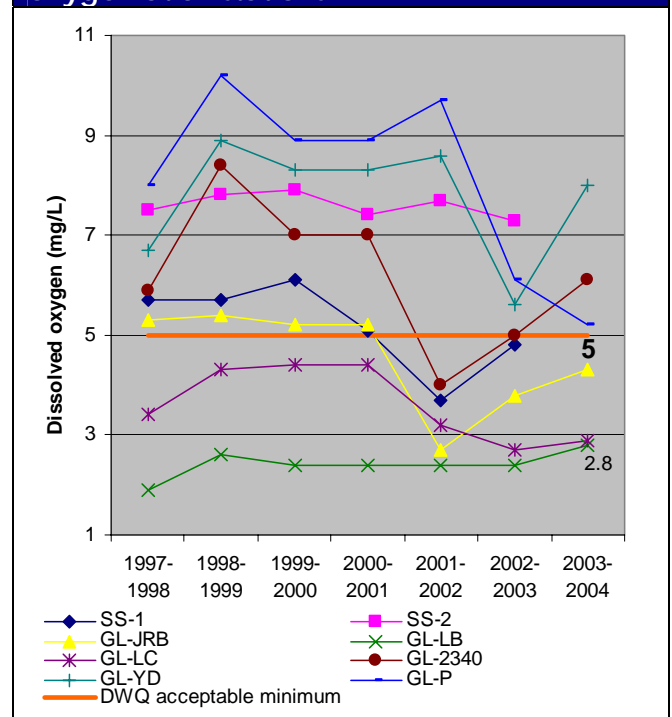


Figure 5.3.4 Greenfield Creek – Dissolved oxygen at all stations



Fecal coliform: Problematic fecal coliform levels have risen in the last few years, in both the tributary stations and the in-lake stations, possibly due to the drought breaking in 2002. Fecal coliform contamination is considered by the Center for Marine Science to be the other impairing parameter in Greenfield Lake in 2002-2003 (Mallin et al. 2004).

Figure 5.3.5 Greenfield Creek – Fecal coliform at all stations but GL-LC

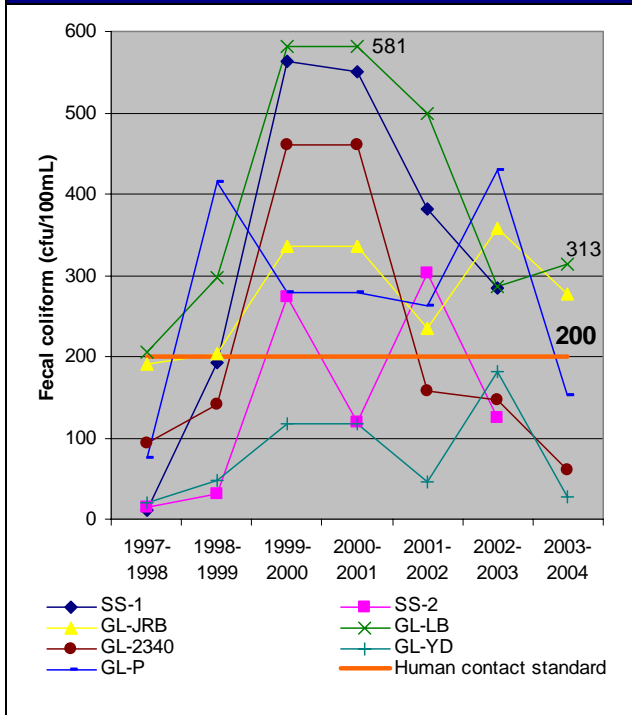
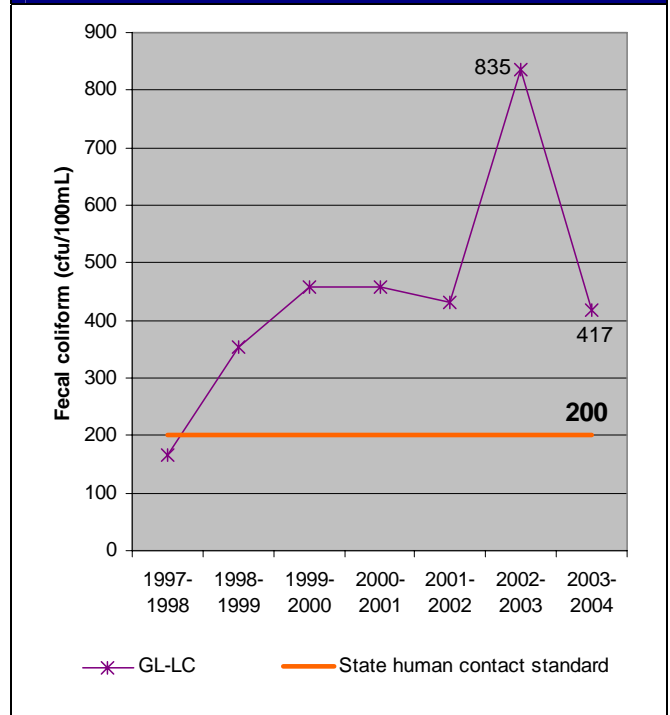


Figure 5.3.6 Greenfield Creek – Fecal coliform at station GL-LC



Watershed Goals

Perpetual

Restore and maintain water quality in Greenfield Creek so that the creek is able to support the uses designated by its classification as a C, Sw waterbody.

- Restore and maintain water quality suitable for secondary recreation.
- Restore and maintain water quality necessary to sustain a healthy aquatic environment.

Long-term

- 1) Reduce nutrient loading.
 - Eliminate algal blooms.
 - Control aquatic weeds.
- 2) Increase and maintain dissolved oxygen levels.
- 3) Reduce bacterial pollution.

Concerns

Aquatic weeds
Nutrients
Low dissolved oxygen
Fecal coliform

Sources

Urban storm water runoff
Suburban storm water runoff

- Reduce fecal coliform bacteria pollution at all stations to levels consistent with NCDENR state standards for human contact (200 colony forming units per 100 milliliters of water).

Short-term

- 1) Identify and manage sources of nutrients.
- 2) Address dissolved oxygen levels, specifically in Jumping Run Branch, the creek at Lake Branch Drive, and the creek beside Lakeshore Commons.
- 3) Identify and reduce sources of fecal coliform bacteria.

Opportunities for Protection, Restoration, and Education

Bacterial Pollution:

- Public education about impervious surface proliferation.
- Efforts to reduce impervious surfaces (in new development, through redevelopment).
- Efforts to reduce runoff from impervious surfaces .
- Public education about pet waste clean up.

Completed Protection Efforts

- The City of Wilmington's Storm Water Services Department and the Cape Fear River Watch used funds from the North Carolina Natural Resources Protection Program's educational outreach grant to hold public meetings, send mailings, and provide school presentations about watersheds, with an emphasis on Greenfield Lake.

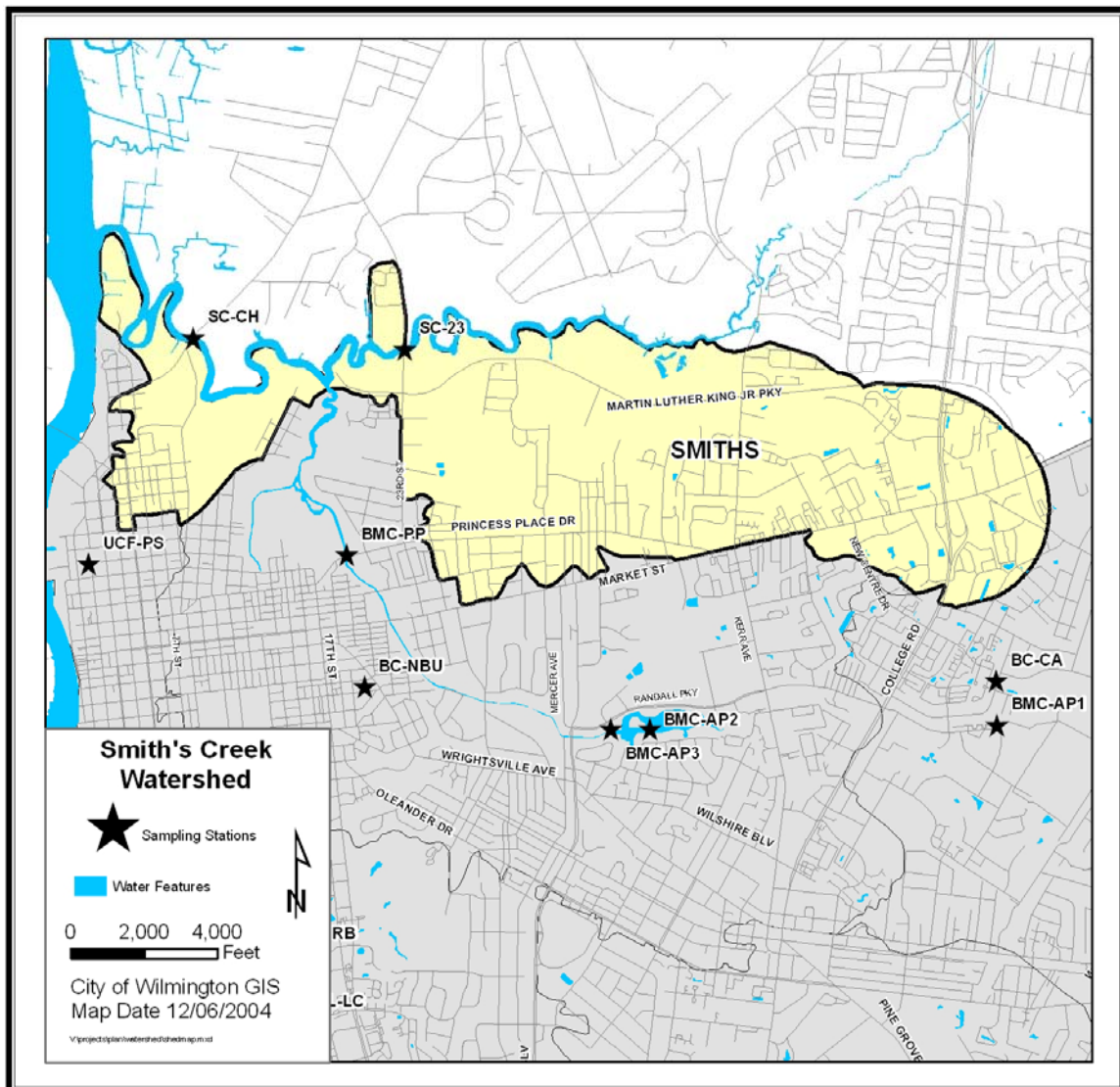
On-going Protection Efforts

- According to the NCDENR Division of Water Quality's *Basinwide Assessment Report: Cape Fear River Basin 2004*, a TMDL for nutrients in Greenfield Lake will be completed in the near future.
- The City Stormwater Services Division has implemented a multi-prong approach to attempt to reduce nuisance aquatic vegetation in Greenfield Lake with apparent short term improvements apparent. The approach includes introduction of sterile grass carp to eat the vegetation, application of an aquatic herbicide, and the use of aeration systems to increase dissolved oxygen.

5.4 Smith Creek

Watershed Description

At 4.5 square miles, Smith Creek is Wilmington's 6th largest watershed. Only the south side of the Smith Creek watershed is within city limits, with the creek providing part of the northern boundary of the city.



Stations

SC-CH: Station closest to mouth, near Castle Hayne Road

SC-23: Midstream station

Major Watershed Landmarks

Wilmington International Airport is located in the northern part of the Smith Creek watershed.

State Classification

Smith Creek is classified as a class **C, SW** water body. This classification means the creek should be able to support secondary recreation as well as wildlife and aquatic life propagation, there are no development restrictions, and it has relatively low velocities. Smith Creek is **not rated** regarding support of these designated uses because the NCDENR Department of Water Quality considers the creek too small to be monitored. Smith Creek is monitored by the UNCW Center for Marine Science and is considered to have some water quality problems.

Primary Land Uses

As with the Greenfield Creek watershed, almost half (44%) of the Smith Creek watershed is vacant land or lands for which the use is unknown. Single family residential accounts for 15% of the land use, commercial accounts for 12%, and industrial accounts for 10%. Multi-family residential and office and institutional are the other two prevalent land uses, each representing approximately 8%. Small amounts of utilities, recreation, mobile homes, and agriculture are also present.

Figure 5.4.1 Smith Creek – Land use in the watershed

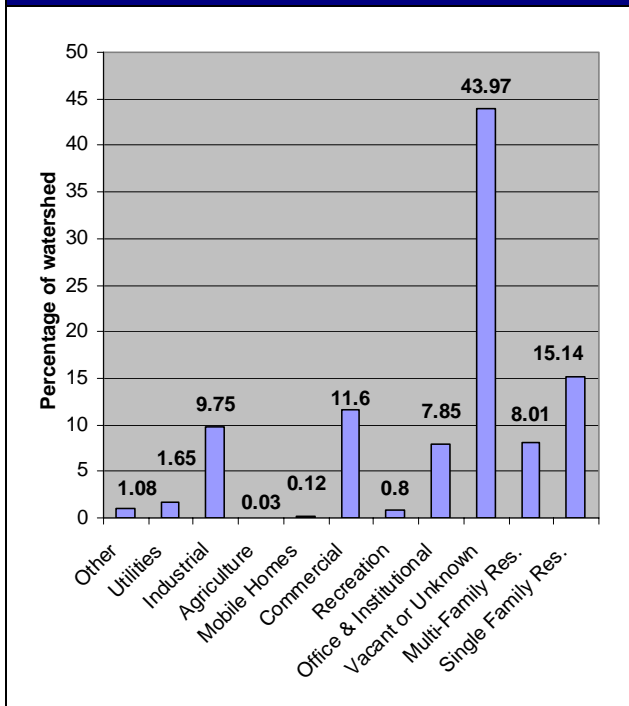
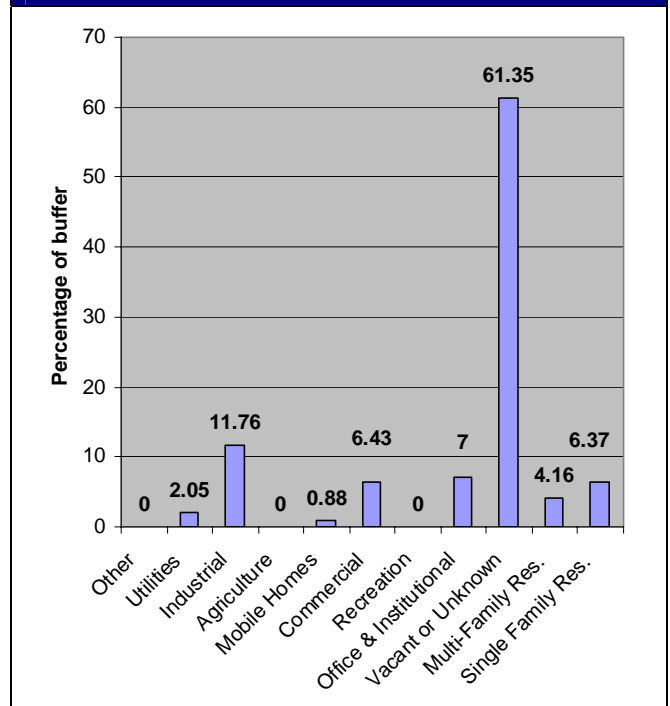


Figure 5.4.2 Smith Creek – Land use in the 1000-foot buffer



Major Pollutants and Water Quality Impacts

The Smith Creek watershed has an impervious surface coverage of 28%, well above the 25% threshold for severe degradation. This impervious coverage percentage, however, was derived only for the portion of the watershed, less than half, that lies within the City Limits. Therefore, no accurate conclusions may be drawn from this comparison.

Low dissolved oxygen: Dissolved oxygen levels have been low in Smith Creek over the last several years (Mallin et al. 2004). As shown in figure 5.4.3, dissolved oxygen levels are at the extreme low end of DWQ's acceptable dissolved oxygen range.

Fecal coliform: Fecal coliform levels in Smith Creek in 2002-2003 exceeded both the human contact standard and the shellfish standard, (Mallin et al. 2004) making the creek unsafe for human contact and the shellfish unsafe for human consumption.

Suspended Solids: Smith Creek maintains some of the highest levels of suspended solids of all the Wilmington watersheds. (Mallin et al. 2004).

Figure 5.4.3 Smith Creek – Dissolved oxygen

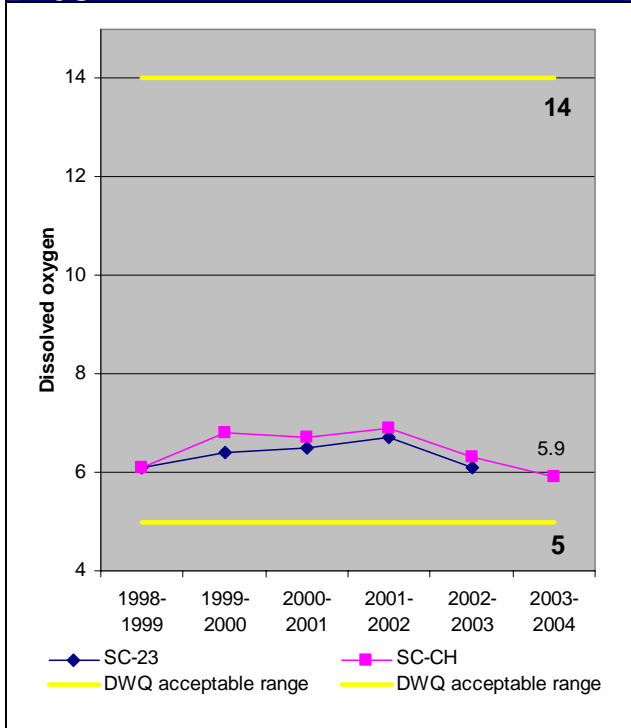
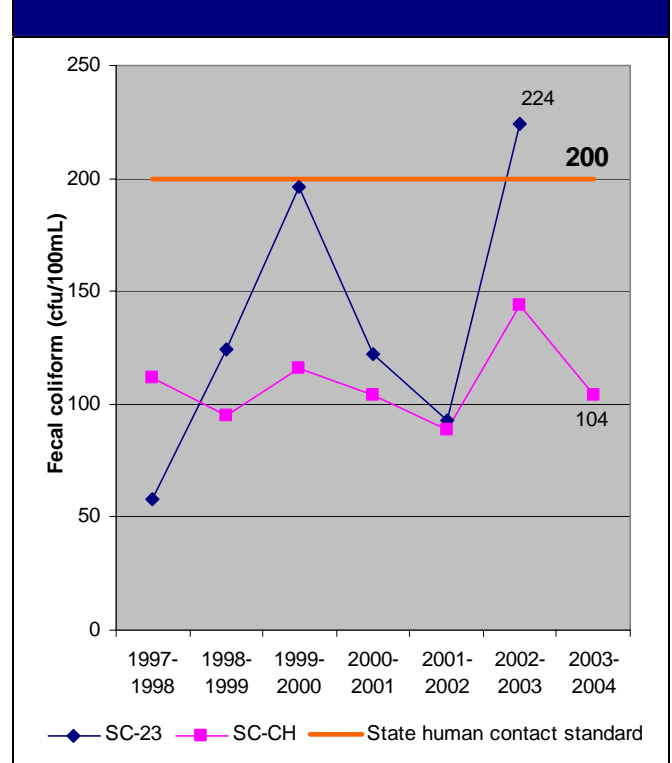


Figure 5.4.4 Smith Creek – Fecal coliform



Other concerns:

- Corning Inc. (permit #NC0003794): discharges cooling water into Spring Branch of Smith Creek.

Watershed Goals

Perpetual

Restore and maintain water quality in Smith Creek so that the creek is able to support the uses designated by its classification as a C, Sw waterbody.

- Restore and maintain water quality suitable for secondary recreation.
- Restore and maintain water quality necessary to sustain a healthy aquatic environment.

Long-term

- Increase and maintain dissolved oxygen levels
- Reduce bacterial pollution.

Concerns

Low dissolved oxygen
Fecal coliform
Suspended solids

Sources

Urban storm water runoff
Suburban storm water runoff

- Reduce fecal coliform bacteria pollution at all stations to levels consistent with NCDENR state standards for human contact (200 colony forming units per 100 milliliters of water).
- 3) Control levels of suspended solids.

Short-term

- 1) Improve dissolved oxygen levels.
- 2) Identify and reduce sources of fecal coliform bacteria.
- 3) Identify and manage sources of suspended solids.

Opportunities for Protection, Restoration, and Education

Completed Protection Efforts

- Stream Restoration (formerly Trask/High property). The owner of a proposed residential subdivision, which has already received site approval, has donated approximately 3.5 acres of conservation easement to the Clean Water Management Trust Fund. The New Hanover County Tidal Creeks Program has completed both stream and wetland restoration on the site (UNCW, *Buffer*).
- The Department of Transportation completed a 4-5 acre wetlands mitigation site on Spring Branch as part of the Martin Luther King Jr. Parkway project.

On-going Protection Efforts

- The Watershed Management Advisory Board has initiated a watershed planning effort for Smith Creek to focus initially on stream buffer preservation.

Appendix A: Current-State Summary of Wilmington's Waters

Table A.1 Current-State Summary of Wilmington's Waters

Tidal / Saltwater ¹							
Water body	Class	Listed 303(d) ²	Status category	Reasons	Sub basin ³	Stream Index ⁴	Threats/ Notes
Bradley Creek	SC, HQW	✓ Listed under DEH Area Assessment Unit B7	7 – High Priority	Fecal coliform	30624 (CPF24)	18-87-24-4	<ul style="list-style-type: none"> Periodic low oxygen events Soils contain slightly elevated levels of cadmium and copper Most heavily impacted tidal creek in this subbasin⁵ Collection system failures Urban runoff/storm sewers Onsite wastewater systems.⁶
Hewlett's Creek	SA, HQW	✓ Listed under DEH Area Assessment Unit B6	7 – Medium Priority	Fecal coliform	30624 (CPF24)	18-87-26	<ul style="list-style-type: none"> Low salinity Nutrients may be flushed from creek quickly Local land use is single family homes with docks Dredging has deepened

¹ NCDENR Division of Water Quality, *North Carolina Waterbodies Listed by County*. Online. Basinwide Information Management System, 22 March 2004 <<http://h2o.enr.state.nc.us/bims/reports/basinsandwaterbodies/NewHanover.pdf>>.

² McNutt, Cam, NCDENR, Division of Water Quality, Basinwide Planning Unit: Cape Fear River Basin. Personal interview. 23 March 2004. See also NCDENR *Impaired Waters List*.

³ NCDENR, Division of Water Quality, *Alphabetic List of NC Waterbodies: Cape Fear River Basin*. Online. Basinwide Information Management System, 22 March 2004 <<http://h2o.enr.state.nc.us/bims/reports/basinsandwaterbodies/alphaCapeFear.pdf>>.

⁴ *Alphabetic List of NC Waterbodies*. Online.

⁵ NCDENR, Division of Water Quality, Environmental Sciences Branch, *Basinwide Assessment Report: Cape Fear River Basin 1999*. Online. 22 March 2004 <<http://h2o.enr.state.nc.us/bims/reports/basinsandwaterbodies/NewHanover.pdf>>.

⁶ *Impaired Waters List*, 14.

							creek since 1996. ⁷ ▪ Agriculture ▪ Urban runoff/storm sewers ▪ Marinas ⁸
Howe Creek	SA, ORW	✓ Listed under DEH Area Assessment Unit B7	7 – High Priority	Fecal coliform	30624 (CPF24)	18-87-23	▪ Collection system failures ▪ Urban runoff/storm sewers ▪ Onsite wastewater systems ⁹
Whiskey Creek	SA, HWQ	✓ Listed under DEH Area Assessment Unit B6	7 – Medium Priority	Fecal coliform	30624 (CPF24)	18-87-28	▪ Agriculture ▪ Urban runoff/storm sewers ▪ Marinas
Cape Fear River – 5000 acres	SC	✓ Listed under DEH Area Assessment Unit B10	5 – High Priority	Low dissolved oxygen.	30617 (CPF17)	18-71	▪ Fish tissue samples from 1998 contained mercury levels higher than EPA limits. ▪ The Wilmington Docks area is the most heavily impacted site in this subbasin, with the lowest Estuarine Biotic Index (EBI 1.24). ▪ Evidence of toxic impacts and low oxygen levels. ▪ Southside WWTP outfall area has oxygen limitation problems. ▪ Relatively stressed community. EBI rating of “Elevated Impact.” ¹⁰
Tributaries/ Freshwater							
Water body	Class	Listed 303(d)	Status category	Reasons	Sub basin	Stream Index	Threats/ Notes

⁷ Basinwide Assessment Report: Cape Fear River Basin 1999. Online.

⁸ Impaired Waters List, 14.

⁹ Impaired Waters List, 14.

¹⁰ Basinwide Assessment Report: Cape Fear River Basin 1999. Online.

Barnard's Creek	C, Sw			Too small and too salty. ¹¹	30617 (CPF17)	18-80	▪ Benthos rating of Fair-Good. ¹² This creek will not be rated in future. ¹³
Burnt Mill Creek - 4.8 miles	C, Sw	✓	6 – High priority	Historical listing for sediment based on biological impairment	30623 (CPF23)	18-74-63-2	▪ Urban runoff/ storm sewers ▪ Dredging ▪ Poor bioclassification rating ¹⁴
Green-field Creek (Green-field Lake) – 115 acres	C, Sw	✓	5 – High priority	Aquatic weeds (Watermeal, duck weed, Brazilian elodea) and nutrients	30617 (CPF17)	18-76-1	
Smith Creek	C, Sw				30623d (CPF23)	18-74-63	
Note: According to NCDENR Basinwide Planning's Cam McNutt, the coordinator for the Cape Fear River Basin Assessment reports, the four tidal creeks in Wilmington are currently listed on the 303(d) list under their Department of Environmental Health Shellfish Sanitation areas B6 and B7. All are listed as impaired. Basinwide Planning is in the process of shifting the creeks from being listed under the DEH Areas, but the change will likely not occur on the 303(d) list until 2008. The change will be reflected in the upcoming 2004 Basinwide Plan. Barnard's Creek and Smith Creek are considered too small to be consistently monitored and will not be included in future Basinwide Assessment reports.							

¹¹ McNutt interview.

¹² *Basinwide Assessment Report: Cape Fear River Basin 1999*. Online.

¹³ McNutt interview.

¹⁴ *Impaired Waters List*, 13.

Appendix B: Water Quality Classifications

Table B.1 Division of Water Quality Tidal Saltwater Classification System Primary Classifications¹⁵

Class	Best Uses
SC	Saltwater Class C: Support aquatic life propagation and maintenance of biological integrity (including fishing, fish, and functioning primary nursery areas (PNA's)), wildlife, secondary recreation (including recreational fishing, boating, and water related activities involving minimal skin contact), and any other usage except primary recreation or shellfishing for market purposes.
SB	Saltwater Class B: Support Primary recreation (including swimming on a frequent or organized basis) and any other usage specified for SC waters.
SA	Saltwater Class A: Support shellfishing for market purposes and any other usage specified for SB or SC waters. All SA waters are also High Quality Waters (HQW).

Table B.2 Division of Water Quality Surface Freshwater Classification System Primary Classifications¹⁶

Class	Best Uses
C	Waters protected for secondary recreation, fishing, wildlife, fish and aquatic life propagation and survival, agriculture and other uses suitable for Class C. There are no restrictions on watershed development of types of use.
B	Waters used for primary recreation and other uses suitable for Class C. There are no restrictions on development of types of discharges
WS-I	Waters used as sources of water supply for drinking, culinary, or food processing purposes for those users desiring maximum protection for their water supplies. WS-I waters are within natural and undeveloped watersheds in public ownership with no point source discharges. All WS-I waters are HQW by definition.
WS-II	Waters used as sources of potable water supply where a WS-I classification is not feasible. WS-II waters are predominantly in undeveloped watersheds, and only general permits for discharges are allowed. All WS-II waters are also HQW.
WS-III	Waters used as sources of potable water supply where more protective WS-I and WS-II classifications are not feasible. WS-III waters are typically in low to moderately developed watershed; general discharge permits only are allowed near the water supply intake whereas domestic and non-process industrial discharges are allowed in the rest of the water supply watershed.
WS-IV	Water used as sources of potable water supply where a WS-I, WS-II, or WS-III classification is not feasible. WS-IV waters are generally located in moderately to highly developed watersheds or Protected Areas, and involve no categorical restrictions on discharge.
WS-V	Waters protected as water supplies that are generally upstream and draining to Class WS-IV waters, waters used by industry to supply their employees with drinking water, or waters formerly used for water supply. Unlike other WS classifications, WS-V has no categorical restrictions on watershed development or wastewater discharges, and local governments are not required to adopt watershed protection ordinances.

¹⁵ North Carolina Department of Environment and Natural Resources, Division of Water Quality Water Quality Section- Planning Branch, *North Carolina Water Quality Assessment and Impaired Waters List February 2003 (02IRMT04Ff)*, (Raleigh, NC, 2003) 10.

¹⁶ North Carolina Department of Environment and Natural Resources, Division of Water Quality, *A Guide to Surface Freshwater Classifications in North Carolina*, Water Quality Planning Branch, (Raleigh, NC, 2001).

Table B.3 Division of Water Quality Supplemental Classifications¹⁷

Class	Best Uses
HQW	High Quality Waters: Waters that are rated as excellent based on biological and physical/chemical characteristics through Division monitoring or special studies, native and special native trout waters (and tributaries) designated by the Wildlife Resources Commission, primary nursery areas (PNA's) designated by the Marine Fisheries Commission, and other functional nursery areas designed by the Marine Fisheries Commission.
NSW	Nutrient Sensitive Waters: Waters that experience or are subject to excessive growths of microscopic or macroscopic vegetation. Excessive growths are growths which the Commission determines impair the use of the water for its best usage as determined by the classification applied to such waters.
ORW	Outstanding Resource Waters: Unique and special surface waters that are of exceptional state or national recreational or ecological significance and that require special protection to maintain existing uses.
Sw	Swamp Waters: Water that are topographically located so as to generally have very low velocities and other characteristics that are different from adjacent streams draining to steeper topography.
Tr	Trout Waters: Waters that have conditions that sustain and allow for trout propagation and survival of stocked trout on a year-round basis.

Table B.4 Classifications of other Divisions¹⁸

Class	Best Uses
Division of Coastal Management (DCM)	
AEC	Estuarine Areas of Environmental Concern: Coastal water and land areas of significant economic and biological values to the state.
Division of Marine Fisheries (DMF)	
PNA	Primary Nursery Areas: Growing areas where populations of juvenile finfish and shellfish of economic importance occur. PNA's are also HQW.
Division of Environmental Health (DEH)	
Approved	Suitable growing area for harvesting shellfish for direct marketing to the public.
Conditionally approved	Growing areas subject to predictable intermittent pollution but are suitable for harvesting shellfish for marketing when Management Plan conditions are met.
Restricted	Growing area suitable for shellfish harvesting by permit only. Shellfish must be purified by approved process.
Prohibited	Area that are unsuitable for harvesting shellfish for direct marketing due to the presence of fecal coliform, point source discharges, or marina, or no current sanitary survey.

¹⁷ North Carolina Department of Environment and Natural Resources, Division of Water Quality Water Quality Section-Planning Branch, *North Carolina Water Quality Assessment and Impaired Waters List February 2003 (02IRMT04Ff)*, (Raleigh, NC, 2003) 10.

¹⁸ North Carolina Department of Environment and Natural Resources, Division of Water Quality, *A Guide to North Carolina's Tidal Saltwater Classifications*, (Raleigh, NC, 2001).

Appendix C: Water Quality Sampling Data

Table C.1 Bradley Creek Water Quality Sampling Data ¹⁹								
	Salinity (ppt)	Turbidity (NTU)	DO (mg/L)	Fecal coliform (CFU/100mL)	Nitrate (mg/L)	Ammonium (mg/L)	Phosphate (mg/L)	Chloro a (ug/L)
State Standard	0.5-37	25	Aquatic life = 5 DWQ = 5 to 14	200	0.2	NA	0.1	Aquatic life = 40 DWQ < 30
STATION								
BC-76								
2003-2004	30.1	5	7.5	NA	0.015	0.023	0.012	1.2
2002-2003	28.8	9	7.7	NA	0.021	0.026	0.007	1.97
2001-2002	34.2	6	6.6	2.7	0.005	0.018	0.009	1.7
2000-2001	32.2	3	6.9	NA	0.004	0.02	0.006	1.6
1999-2000	31.6	6.2	6.7	NA	0.01	0.018	0.008	1.3
1998-1999	31.8	8.9	6.9	7	0.009	0.018	0.007	1.4
1997-1998	28.5	13.7	6.7	9	0.013	0.018	0.006	2.5
1993-1997	30.2	NA	6	21	0.017	NA	0.004	3.8
BC-SB								
2003-2004	8.0	7	8.0	NA	0.070	0.024	0.013	5.1
2002-2003	12.5	25	7.4	NA	0.088	0.036	0.011	3.2
2001-2002	18.5	9	7.1	156	0.019	0.025	0.009	11.3
2000-2001	15.4	10	7	NA	0.046	0.026	0.011	12.9
1999-2000	8.3	11.6	6.9	NA	0.072	0.036	0.011	8.4
1998-1999	9.6	16.8	7.5	363	0.07	0.046	0.014	6.8
1997-1998	4.6	26.8	7.5	417	0.073	0.046	0.009	19.9
1993-1997	13.6	NA	6.3	473	0.068	NA	0.008	23.7
BC-SBU								
2003-2004	0.1	4	8.1	NA	0.083	NA	0.011	2.3
2002-2003	0.1	6	7.2	NA	0.186	NA	0.009	2.5
2001-2002	0.2	3	8.9	138	0.089	NA	0.01	4.7
2000-2001	0.1	7	7.7	NA	0.107	NA	0.012	5.4
1999-2000	0.1	6.5	6.6	NA	0.143	NA	0.011	3.1
1998-1999	0.1	5.5	6.9	393	0.126	NA	0.009	1.7
1997-1998	0.2	4.7	6.7	278	0.205	NA	0.008	1.8
1993-1997	2.8	NA	6.3	483	0.095	NA	0.013	5.9
BC-NB								
2003-2004	15.9	10	7.3	NA	0.042	0.029	0.011	3.7

¹⁹ Data obtained from the New Hanover County Tidal Creeks Program's annual *Environmental Quality of Wilmington and New Hanover County Watersheds* reports from 1997 to 2003, produced by the University of North Carolina at Wilmington's Center for Marine Science Research.

2002-2003	21.1	10	7.1	NA	0.029	NA	0.009	3.9
2001-2002	27.2	7	6.6	25	0.005	0.016	0.008	5.3
2000-2001	23	6	6.6	NA	0.025	0.023	0.012	4.5
1999-2000	24.4	10.6	6.4	NA	0.028	0.032	0.01	3.5
1998-1999	24.6	10.5	7.2	81	0.027	0.044	0.006	2.1
1997-1998	13.9	26	6.8	197	0.084	0.044	0.007	9.9
1993-1997	21.3	NA	6	86	0.039	NA	0.005	6.5
BC-NBU								
2003-2004	0.1	15	7.7	NA	0.087	NA	0.005	0.5
2002-2003	0.1	9	7.6	NA	0.116	NA	0.004	1.5
2001-2002	0.1	3	7.4	167	0.08	NA	0.007	0.7
2000-2001	0.1	9	7.6	NA	0.1	NA	0.003	4.5
1999-2000	0.1	6.4	7.6	NA	0.128	NA	0.004	2.1
1998-1999	0.1	18.6	7.7	155	0.132	NA	0.003	0.7
1997-1998	0.1	66.9	7.2	182	0.121	NA	0.006	2.2
1993-1997	3.5	NA	6.5	321	0.092	NA	0.004	3.4
BC-CR								
2003-2004	0.1	3	7.9	NA	0.274	NA	0.007	0.4
2002-2003	0.1	4	7.6	NA	0.27	NA	0.005	1.8
2001-2002	0.1	2	8.2	213	0.229	NA	0.006	1.1
2000-2001	0.1	2	7.4	NA	0.251	NA	0.009	0.8
1999-2000	0.1	7.7	7.2	NA	0.268	NA	0.007	1.4
1998-1999	0.1	3.1	7.7	235	0.239	NA	0.006	0.8
1997-1998	0.1	3.1	7	25	0.236	NA	0.007	0.7
1993-1997	NA	NA	NA	NA	NA	NA	NA	NA
BC-CA								
2003-2004	0.1	7	6.4	807	0.085	0.121	0.019	11.2
2002-2003	0.1	8	6.3	1093	0.09	0.125	0.021	10.6
2001-2002	0.1	9	4.1	1169	0.57	0.083	0.109	15.1
2000-2001	0.1	7	5.8	614	0.074	0.051	0.034	7.1
1999-2000	0.1	10.7	6.1	616	0.222	0.098	0.038	7.8
1998-1999	0.1	13.9	6	616	0.084	0.082	0.037	3.5
1997-1998	0.1	38.3	6.4	143	0.173	0.14	0.073	6.5
1993-1997	NA	NA	NA	NA	NA	NA	NA	NA

Table C.2 Hewlett's Creek Water Quality Sampling Data²⁰

	Salinity (ppt)	Turbidity (NTU)	DO (mg/L)	Fecal coliform (CFU/100mL)	Nitrate (mg/L)	Ammonium (mg/L)	Phosphate (mg/L)	Chloro a (ug/L)
State Standard	0.5-37	25	Aquatic life = 5 DWQ = 5 to 14	200	0.2	NA	0.1	Aquatic life = 40 DWQ = < 30
STATION								
HC-M								
2003-2004	32.7	4	8.3	3	0.007	0.015	0.007	1.1
2002-2003	~	~	~	~	~	~	~	~
2001-2002	~	~	~	~	~	~	~	~
2000-2001	34.6	4	7.8	2	0.005	0.016	0.004	1.4
1999-2000	~	~	~	~	~	~	~	~
1998-1999	~	~	~	~	~	~	~	~
1997-1998	~	~	~	~	~	~	~	~
1993-1997	~	~	~	~	~	~	~	~
HC-1								
2003-2004	~	~	~	~	~	~	~	~
2002-2003	~	~	~	~	~	~	~	~
2001-2002	~	~	~	~	~	~	~	~
2000-2001	~	~	~	~	~	~	~	~
1999-2000	~	~	~	~	~	~	~	~
1998-1999	~	~	~	~	~	~	~	~
1997-1998	~	~	~	~	~	~	~	~
1993-1997	34	NA	7.2	5	0.007	NA	0.004	2.4
HC-2								
2003-2004	32.8	4	8.1	3	0.009	0.015	0.008	1.1
2002-2003	32.6	4	7.8	NA	0.008	0.019	0.004	1.3
2001-2002	34.8	4	7.7	NA	0.004	0.013	0.007	1.3
2000-2001	34.3	4	7.6	2	0.005	0.019	0.005	1.6
1999-2000	33.5	4.9	7.6	NA	0.007	0.015	0.005	1.4
1998-1999	30.3	9.9	8.3	NA	0.014	0.027	0.006	1
1997-1998	28	19.7	7.5	NA	0.013	0.027	0.008	1.6
1993-1997	32.6	NA	7.1	10	0.008	NA	0.004	2.7
HC-3								
2003-2004	29.5	6	7.9	17	0.015	NA	0.009	1.4
2002-2003	30.4	6	7.6	NA	0.013	NA	0.005	1.7
2001-2002	32.7	6	7.6	NA	0.004	NA	0.007	2.2
2000-2001	31.2	5	7.2	11	0.011	0.023	0.006	2.1
1999-2000	32.1	5.8	7.4	NA	0.004	0.005	0.005	1.9
1998-1999	~	~	~	~	~	~	~	~
1997-1998	~	~	~	~	~	~	~	~
1993-1997	28.8	NA	6.9	55	0.014	NA	0.004	4.6

²⁰ NHC Tidal Creeks Program. See footnote 19.

HC-NWB								
2003-2004	19.5	10	7.2	91	0.036	0.027	0.011	2.9
2002-2003	~	~	~	~	~	~	~	~
2001-2002	~	~	~	~	~	~	~	~
2000-2001	22.2	8	6.9	68	0.043	NA	0.009	3.6
1999-2000	~	~	~	~	~	~	~	~
1998-1999	~	~	~	~	~	~	~	~
1997-1998	~	~	~	~	~	~	~	~
1993-1997	20.9	NA	6.9	126	0.078	NA	0.006	5
NB-GLR								
2003-2004	8.2	10	7.5	292	0.108	0.022	0.021	12.2
2002-2003	8	13	15	NA	0.119	0.046	0.018	19
2001-2002	15.7	15	8.2	NA	0.025	0.037	0.015	10.3
2000-2001	15.4	10	6.5	68	0.079	0.042	0.013	6.3
1999-2000	9.2	12.3	7.6	NA	0.131	0.061	0.018	13.5
1998-1999	5.8	15.3	7.8	NA	0.105	0.039	0.019	7.1
1997-1998	9	26.2	7.5	NA	0.1	0.039	0.013	12.7
1993-1997	13.9	NA	6.5	266	0.099	NA	0.011	10.9
SB-PGR								
2003-2004	15.6	10	7.1	136	0.056	0.034	0.012	4
2002-2003	17.2	15	7.4	NA	0.049	0.052	0.008	11.5
2001-2002	22.7	12	7.9	NA	0.01	0.021	0.01	11.9
2000-2001	16.6	14	6.9	118	0.062	0.034	0.012	13.9
1999-2000	19.3	12.2	6.7	NA	0.057	0.038	0.012	5.5
1998-1999	12.6	21.7	7.3	NA	0.06	0.014	0.014	9.9
1997-1998	13.9	26.4	7.2	NA	0.039	0.014	0.012	29.2
1993-1997	19.4	NA	6.8	212	0.057	NA	0.006	17.6
MB-PGR								
2003-2004	0.3	3	7.7	171	0.221	0.026	0.015	1.1
2002-2003	0.4	7	7.8	NA	0.235	0.03	0.014	3.1
2001-2002	0.8	2	7	NA	0.157	0.032	0.017	1.2
2000-2001	0.2	6	7	266	0.235	0.032	0.016	1.3
1999-2000	0.2	5	6.7	NA	0.311	NA	0.026	0.7
1998-1999	0.1	8.5	7.1	NA	0.226	NA	0.014	1.3
1997-1998	1.2	11.3	6.7	NA	0.232	NA	0.014	4.1
1993-1997	2.2	NA	6.3	378	0.228	NA	0.011	2.3
PVGC-9								
2003-2004	0.1	3	6.6	363	0.343	0.046	0.007	1.7
2002-2003	0.1	4	6.5	537	0.417	0.181	0.016	2.5
2001-2002	0.1	3	6.2	244	0.283	0.164	0.184	2.5
2000-2001	0.1	11	6.7	362	0.326	0.043	0.043	2.8
1999-2000	NA	5.1	6.7	303	0.278	0.052	0.033	1.3
1998-1999	~	~	~	~	~	~	~	~
1997-1998	~	~	~	~	~	~	~	~
1993-1997	~	~	~	~	~	~	~	~
HC-LO								
2003-2004	~	~	~	~	~	~	~	~
2002-2003	~	~	~	~	~	~	~	~

2001-2002	~	~	~	~	~	~	~	~
2000-2001	~	~	~	~	~	~	~	~
1999-2000	~	~	~	~	~	~	~	~
1998-1999	~	~	~	~	~	~	~	~
1997-1998	NA	8.8	5.9	35	0.067	0.126	0.018	2.2
1993-1997	~	~	~	~	~	~	~	~

Table C.3 Howe Creek Water Quality Sampling Data²¹

	Salinity (ppt)	Turbidity (ntu)	DO (mg/L)	Fecal coliform (CFU/100mL)	Nitrate (mg/L)	Ammonium (mg/L)	Phosphate (mg/L)	Chloro a (ug/L)
State Standard	0.5-37	25	Aquatic life = 5 DWQ = 5 to 14	200	0.2	NA	0.1	Aquatic life = 40 DWQ = < 30
STATION								
HW-M								
2003-2004	34.2	4	8	3	0.005	0.014	0.007	1.2
2002-2003	33.1	6	7.6	3	0.007	0.022	0.004	1.6
2001-2002	35.6	6	7.3	1	0.003	0.015	0.007	1.3
2000-2001	~	~	~	~	~	~	~	~
1999-2000	30.1	5.9	7.2	4	0.006	0.007	0.006	1.7
1998-1999	~	~	~	~	~	~	~	~
1997-1998	~	~	~	~	~	~	~	~
1993-1997	32.4	7.2	7.6	3	0.008	NA	0.005	2.5
HW-FP								
2003-2004	33.7	4	7.9	5	0.007	0.013	0.008	0.9
2002-2003	33.1	5	7.5	1	0.006	0.021	0.005	1.3
2001-2002	35.4	6	7.4	1	0.003	0.019	0.008	1.1
2000-2001	34.6	4	7.4	NA	0.004	0.022	0.005	2
1999-2000	27.2	18.3	7.2	6	0.006	0.013	0.006	1.4
1998-1999	33.9	5.2	7.5	NA	0.004	0.019	0.006	1.4
1997-1998	29.8	6.8	6.6	NA	0.006	0.019	0.006	2.8
1993-1997	32.1	6.5	7.5	5	0.004	NA	0.004	2.9
HW-GC								
2003-2004	29.3	6	7.6	21	0.008	NA	0.010	1.3
2002-2003	29.7	8	7.2	23	0.008	NA	0.006	2.4
2001-2002	34	7	7.2	8	0.004	NA	0.008	1.6
2000-2001	30.2	8	7.4	NA	0.005	NA	0.006	2.3
1999-2000	22	16.7	7.5	18	0.013	NA	0.008	2
1998-1999	28.2	12.2	7.4	NA	0.012	NA	0.007	2
1997-1998	25.9	15.9	6.6	NA	0.012	NA	0.008	2.4
1993-1997	24.6	8.2	6.8	19	0.014	NA	0.005	5.8
HW-GP								
2003-2004	14.5	10	7.4	185	0.022	0.019	0.011	6.5
2002-2003	19.2	8	6.9	93	0.012	0.023	0.006	6
2001-2002	25.4	11	6.9	81	0.006	0.02	0.01	6.4
2000-2001	18.7	9	6.8	NA	0.023	0.041	0.007	8
1999-2000	0.2	6.6	7.2	171	0.025	0.018	0.008	5.9
1998-1999	13.5	14.7	7.5	NA	0.035	0.013	0.013	8
1997-1998	13.9	31.9	6.5	NA	0.038	0.013	0.008	12.5

²¹ NHC Tidal Creeks Program. See footnote 19.

1993-1997	14.4	14.2	6.8	170	0.045	NA	0.008	15.5
HW-DT								
2003-2004	4.2	15	8.6	419	0.047	0.023	0.012	10.2
2002-2003	4.2	13	7.9	201	0.027	0.029	0.008	20.3
2001-2002	13.4	11	7.7	214	0.011	0.021	0.011	10.4
2000-2001	~	~	~	~	~	~	~	~
1999-2000	0.2	7.9	7	367	0.07	0.028	0.013	23.3
1998-1999	~	~	~	~	~	~	~	~
1997-1998	~	~	~	~	~	~	~	~
1993-1997	5.3	19	6.8	387	0.049	NA	0.007	33.6

Table C.4 Whiskey Creek Water Quality Sampling Data²²

	Salinity (ppt)	Turbidity (ntu)	DO (mg/L)	Fecal coliform (CFU/100mL)	Nitrate (mg/L)	Ammonium (mg/L)	Phosphate (mg/L)	Chloro a (ug/L)
State Standard	0.5-37	25	Aquatic life = 5 DWQ = 5 to 14	200	0.2	NA	0.1	Aquatic life = 40 DWQ = < 30
STATION								
WC-MB								
2003-2004	29.7	5	7.8	NA	0.025	0.028	0.011	2
2002-2003	29	7	7.4	8	0.028	0.049	0.008	2.7
2001-2002	33.7	7	6.6	NA	0.008	0.03	0.01	2
2000-2001	31.2	6	6.8	NA	0.015	0.034	0.01	2.7
1999-2000	30.1	5.9	7.2	12	0.017	0.019	0.011	1.9
1998-1999	~	~	~	~	~	~	~	~
1997-1998	~	~	~	~	~	~	~	~
1993-1997	~	~	~	~	~	~	~	~
WC-AB								
2003-2004	27.3	7	7.9	NA	0.034	NA	0.015	1.6
2002-2003	25.2	11	7.5	47	0.037	NA	0.009	3.2
2001-2002	32.2	10	6.5	NA	0.012	NA	0.013	2.6
2000-2001	27.7	11	6.8	NA	0.019	NA	0.012	4.2
1999-2000	30.1	18.3	7.2	36	0.022	0.021	0.012	2.5
1998-1999	~	~	~	~	~	~	~	~
1997-1998	~	~	~	~	~	~	~	~
1993-1997	~	~	~	~	~	~	~	~
WC-MLR								
2003-2004	24.1	9	7.7	NA	0.036	0.043	0.014	2.3
2002-2003	20.4	15	7.5	82	0.049	0.072	0.009	4.5
2001-2002	30.9	11	6.1	NA	0.013	0.037	0.016	3.6
2000-2001	19.9	13	7	NA	0.018	0.0145	0.012	5.6
1999-2000	22	16.7	7.5	93	0.027	0.024	0.011	4.8
1998-1999	~	~	~	~	~	~	~	~
1997-1998	~	~	~	~	~	~	~	~
1993-1997	~	~	~	~	~	~	~	~
WC-SB								
2003-2004	0.1	14	7.7	NA	0.063	0.101	0.003	0.4
2002-2003	0.2	9	7.9	134	0.089	0.106	0.002	1
2001-2002	0.1	5	6.9	NA	0.082	0.106	0.007	0.6
2000-2001	0.1	5	7.1	NA	0.05	0.098	0.003	1.4
1999-2000	0.2	6.6	7.2	179	0.091	0.082	0.013	0.8
1998-1999	~	~	~	~	~	~	~	~
1997-1998	~	~	~	~	~	~	~	~
1993-1997	~	~	~	~	~	~	~	~

²² NHC Tidal Creeks Program. See footnote 19.

WC-NB								
2003-2004	0.2	6	6.8	NA	0.196	0.113	0.007	0.3
2002-2003	0.2	10	7.8	366	0.214	0.15	0.007	0.3
2001-2002	0.2	6	4.8	NA	0.142	0.09	0.005	0.5
2000-2001	0.2	6	6.2	NA	0.17	0.099	0.011	1
1999-2000	0.2	7.9	7	408	0.151	0.081	0.01	0.8
1998-1999	~	~	~	~	~	~	~	~
1997-1998	~	~	~	~	~	~	~	~
1993-1997	~	~	~	~	~	~	~	~

Table C.5 Lower Cape Fear River Water Quality Sampling Data²³

	Salinity (ppt)	Turbidity (ntu)	DO (mg/L)	Fecal coliform (CFU/ 100mL)	Nitrate (mg/L)	Ammonium (mg/L)	Phosphate (mg/L)	Chloro a (ug/L)	Total Suspended Solids (mg/L)
State Standard	0.5-37	25	Aquatic life = 5 DWQ = 5 to 14	200	0.2	NA	0.1	Aquatic life = 40 DWQ = < 30	NA
STATION									
NCF6									
2002-2003	2.8	16	6.9	38	0.259	0.088	0.043	3.4	17
2001-2002	3.8	17	6.8	36	0.298	0.081	0.05	4.6	13.2
2000-2001	1.6	14	6.7	31	0.202	0.077	0.039	1.9	10
1999-2000	1.5	12	6.8	27	0.298	0.088	0.039	1.3	8
1998-1999	3.4	18	6.1	236	0.306	0.068	0.046	3.5	10
1997-1998	1.4	15.4	6.2	53	0.283	0.041	0.038	2.9	8
M61									
2002-2003	6.3	23	7.6	27	0.426	0.12	0.051	3.4	15
2001-2002	9.3	14	7.2	59	0.39	0.136	0.058	6.1	8.5
2000-2001	6.5	16	6.8	100	0.284	0.132	0.056	3.2	10
1999-2000	3.3	21	7	39	0.391	0.106	0.048	3.1	8
1998-1999	6.8	16	6.4	223	0.396	0.095	0.053	3.2	10
1997-1998	3.8	28.3	6.6	64	0.338	0.082	0.044	5.2	13
M54									
2002-2003	8	27	8	24	0.477	125	0.047	4.9	21
2001-2002	12.2	15	7.7	16	0.348	135	0.04	5	12.7
2000-2001	8.8	18	7.2	124	0.258	135	0.053	5	16
1999-2000	5.1	23	7.3	31	0.353	109	0.044	3	17
1998-1999	8.7	22	6.7	50	0.368	108	0.051	3.8	13
1997-1998	5.7	32.4	6.8	52	0.33	81	0.04	6.5	22

²³ Data obtained from the Lower Cape Fear River Program's annual reports, *Environmental Assessment of the Lower Cape Fear River System*, from 1997 to 2003, produced by the University of North Carolina at Wilmington's Center for Marine Science Research.

Table C.6 Barnard's Creek Water Quality Sampling Data

	Turbidity (ntu)	DO (mg/L)	Fecal coliform (CFU/100mL)	Nitrate (mg/L)	Ammonium (mg/L)	Phosphate (mg/L)	Chloro a (ug/L)	Total Suspended Solids (mg/L)
State Standard	Aquatic life = < 50 DWQ = < 25	Aquatic life = 5 Swamp = 4 DWQ = 5 to 14	200	DWQ = < 0.5	NA	DWQ = < 0.2	Aquatic life = 40 DWQ = < 30	NA
STATION								
BNC-TR								
2003-2004	~	~	~	~	~	~	~	~
2002-2003	90	4.8	307	0.06	0.109	0.05	0.8	13.8
2001-2002	4	6.2	415	0.066	0.074	0.015	2.4	5.3
2000-2001	3	6.8	257	0.075	0.013	0.027	1.1	5.9
1999-2000	7.7	6.5	336	0.093	0.035	0.023	0.7	3.9
1998-1999	3.8	6.5	154	0.022	0.019	0.019	1.3	4.6
1997-1998	6	6.8	63	0.013	0.018	0.021	1	2.5
1993-1997	~	~	~	~	~	~	~	~
BNC-CB								
2003-2004	~	~	~	~	~	~	~	~
2002-2003	12	6.9	505	0.069	0.092	0.034	2.9	5.4
2001-2002	5	7.5	348	0.088	0.088	0.034	3.1	3.5
2000-2001	9	7.3	272	0.056	0.031	0.024	1	6
1999-2000	10.5	7.3	238	0.108	0.084	0.018	1.7	3.9
1998-1999	6.9	6.6	173	0.043	0.031	0.012	1.1	2.8
1997-1998	15.7	6.7	78	0.073	0.054	0.027	1.8	2.2
1993-1997	~	~	~	~	~	~	~	~
BNC-RR								
2003-2004	21	6.1	121	0.140	0.247	0.042	3.5	24.7
2002-2003	44	6.5	96	0.215	0.123	0.067	4.9	38.5
2001-2002	29	6.8	112	0.24	0.142	0.108	8.3	44.7
2000-2001	22	6.8	100	0.156	0.018	0.079	6.7	20.9
1999-2000	29.8	7.5	102	0.238	0.053	0.078	2.6	29.4
1998-1999	18.4	7.4	59	0.191	0.122	0.091	3.8	16.3
1997-1998	~	~	~	~	~	~	~	~
1993-1997	~	~	~	~	~	~	~	~
BNC-EF								
2003-2004	~	~	~	~	~	~	~	~
2002-2003	~	~	~	~	~	~	~	~
2001-2002	~	~	~	~	~	~	~	~
2000-2001	2	5.7	130	0.047	0.027	0.028	2.8	4
1999-2000	2.6	6	128	0.101	0.032	0.023	2.2	5
1998-1999	4.9	6.2	92	0.012	0.017	0.02	4.2	4.1
1997-1998	18.1	6.4	44	0.073	0.054	0.035	1.6	3
1993-1997	~	~	~	~	~	~	~	~

BNC-AW								
2003-2004	~	~	~	~	~	~	~	~
2002-2003	~	~	~	~	~	~	~	~
2001-2002	~	~	~	~	~	~	~	~
2000-2001	2	6.2	168	0.083	0.033	0.045	3.3	6.7
1999-2000	4.1	5.8	137	0.126	0.043	0.038	2.9	4.8
1998-1999	4.3	6.3	170	0.012	0.017	0.055	1.7	3.4
1997-1998	14.8	6.4	27	0.059	0.03	0.041	1.9	5
1993-1997	~	~	~	~	~	~	~	~

Table C.7 Burnt Mill Creek Water Quality Sampling Data

	Turbidity (ntu)	DO (mg/L)	Fecal coliform (CFU/100mL)	Nitrate (mg/L)	Ammonium (mg/L)	Phosphate (mg/L)	Chloro a (ug/L)	Total Suspended Solids (mg/L)
State Standard	Aquatic life = < 50 DWQ = < 25	Aquatic life = 5 Swamp = 4 DWQ = 5 to 14	200	DWQ = < 0.5	NA	DWQ = < 0.2	Aquatic life = 40 DWQ = < 30	NA
STATION								
BMC-AP1								
2003-2004	5	6.5	927	0.079	0.057	0.012	13.3	4.7
2002-2003	9	6.6	1162	0.104	0.094	0.013	12.2	8.9
2001-2002	8	5.3	564	0.05	0.114	0.112	13.1	8.4
2000-2001	18	5.7	392	0.069	0.068	0.041	4.5	11.5
1999-2000	7.4	6.7	569	0.35	0.133	0.018	1.2	2.5
1998-1999	20.8	7.8	624	0.076	0.055	0.018	2.8	20.6
1997-1998	33.1	6.5	303	0.143	0.094	0.041	2.8	5.7
1993-1997	~	~	~	~	~	~	~	~
BMC-AP2								
2003-2004	~	~	~	~	~	~	~	~
2002-2003	~	~	~	~	~	~	~	~
2001-2002	~	~	~	~	~	~	~	~
2000-2001	9	8.8	165	0.121	0.038	0.026	17.7	11.5
1999-2000	7.6	8.3	197	0.159	0.065	0.018	3.3	5
1998-1999	4	9	69	0.033	0.015	0.015	3	2.5
1997-1998	24	7.3	108	0.229	0.088	0.038	10	5.8
1993-1997	~	~	~	~	~	~	~	~
BMC-AP3								
2003-2004	8	9.5	74	0.056	0.081	0.007	13.7	5.7
2002-2003	9	9.1	285	0.061	0.081	0.026	16.3	6.4
2001-2002	9	9.3	128	0.029	0.074	0.064	13.9	5.3
2000-2001	6	9.8	121	0.142	0.034	0.022	10.7	5.5
1999-2000	5.9	9.6	114	0.3	0.067	0.024	3.4	3.2
1998-1999	3.9	9.6	54	0.021	0.019	0.02	3.1	2.7
1997-1998	15	8.9	39	0.209	0.067	0.025	8.2	4.7
1993-1997	~	~	~	~	~	~	~	~
BMC-PP								
2003-2004	5	4.9	639	0.115	0.096	0.021	8	5
2002-2003	7	5.7	914	0.113	0.121	0.042	7.5	7.3
2001-2002	19	5.6	510	0.107	0.106	0.062	14.6	11.7
2000-2001	9	6	328	0.231	0.03	0.044	14.8	9.1
1999-2000	17.1	5	585	0.277	0.063	0.038	2.9	4.9
1998-1999	6.9	6	512	0.117	0.079	0.035	4.9	7
1997-1998	15.8	5.2	295	0.221	0.135	0.051	5.6	9.5
1993-1997	~	~	~	~	~	~	~	~

Table C.8 Greenfield Creek Water Quality Sampling Data

	Turbidity (ntu)	DO (mg/L)	Fecal coliform (CFU/100mL)	Nitrate (mg/L)	Ammonium (mg/L)	Phosphate (mg/L)	Chloro a (ug/L)	Total Suspended Solids (mg/L)
State Standard	Aquatic life = < 50 DWQ = < 25	Aquatic life = 5 Swamp = 4 DWQ = 5 to 14	200	DWQ = < 0.5	NA	DWQ = < 0.2	Aquatic life = 40 DWQ = < 30	NA
STATION								
SS-1								
2003-2004	~	~	~	~	~	~	~	~
2002-2003	3	4.8	285	0.45	0.232	0.11	1.5	7.1
2001-2002	3	3.7	381	0.315	0.228	0.382	3.4	3.5
2000-2001	6	5.1	551	0.294	0.056	0.129	4.5	6
1999-2000	4.7	6.1	564	0.366	0.156	0.071	2.4	2.3
1998-1999	3.5	5.7	193	0.23	0.06	0.1	2.5	3.8
1997-1998	12	5.7	11	0.29	0.1	0.11	5.5	6.3
1993-1997	~	~	~	~	~	~	~	~
SS-2								
2003-2004	~	~	~	~	~	~	~	~
2002-2003	6	7.3	124	0.069	0.209	0.02	17	6.1
2001-2002	5	7.7	302	0.055	0.146	0.043	11.6	3.7
2000-2001	5	7.4	120	0.081	0.034	0.043	9.2	4.6
1999-2000	5.5	7.9	273	0.152	0.093	0.028	8.2	4.1
1998-1999	4	7.8	31	0.04	0.03	0.02	4	9.3
1997-1998	7.9	7.5	15	0.13	0.04	0.02	6.5	2.5
1993-1997	~	~	~	~	~	~	~	~
GL-JRB								
2003-2004	3	4.3	277	0.093	0.086	0.023	4.1	3
2002-2003	6	3.8	357	0.11	0.155	0.027	7.4	4.4
2001-2002	4	2.7	234	0.085	0.136	0.038	9.3	4.1
2000-2001	12.7	5.2	336	0.203	0.085	0.033	3.6	5.1
1999-2000	12.7	5.2	336	0.203	0.085	0.033	3.6	5.1
1998-1999	3.4	5.4	204	0.083	0.048	0.038	2.2	2.8
1997-1998	6.9	5.3	191	0.17	0.181	0.057	3.6	2.5
1993-1997	~	~	~	~	~	~	~	~
GL-LB								
2003-2004	2	2.8	313	0.244	0.189	0.026	1.8	2.9
2002-2003	5	2.4	287	0.179	0.222	0.029	4	3.7
2001-2002	6	2.4	499	0.062	0.157	0.045	9.5	6.5
2000-2001	7.2	2.4	581	0.17	0.094	0.047	3.7	4
1999-2000	7.2	2.4	581	0.17	0.094	0.047	3.7	4
1998-1999	4.4	2.6	298	0.18	0.101	0.037	1.4	2.7
1997-1998	4.8	1.9	205	0.283	0.175	0.057	2	2.8
1993-1997	~	~	~	~	~	~	~	~

GL-LC								
2003-2004	3	2.9	417	0.457	0.100	0.023	15.6	3.6
2002-2003	4	2.7	835	0.341	0.163	0.066	5.9	13.6
2001-2002	5	3.2	430	0.305	0.12	0.213	5.6	4.2
2000-2001	3.3	4.4	457	0.368	0.098	0.043	4.5	2
1999-2000	3.3	4.4	457	0.368	0.098	0.043	4.5	2
1998-1999	2.6	4.3	354	0.572	0.085	0.06	1.9	2.5
1997-1998	4.7	3.4	166	0.835	0.101	0.066	5.6	3.3
1993-1997	~	~	~	~	~	~	~	~
GL-2340								
2003-2004	2	6.1	61	0.109	0.024	0.009	31.6	4.6
2002-2003	2	5	147	0.098	0.119	0.013	7.2	4
2001-2002	5	4	158	0.151	0.127	0.197	24.8	4.4
2000-2001	5.8	7	460	0.179	0.039	0.031	7.2	4.4
1999-2000	5.8	7	460	0.179	0.039	0.031	7.2	4.4
1998-1999	5	8.4	141	0.113	0.022	0.025	17.3	5.8
1997-1998	4.9	5.9	93	0.196	0.055	0.018	11.7	4.3
1993-1997	~	~	~	~	~	~	~	~
GL-YD								
2003-2004	2	8	28	0.060	0.044	0.010	11	6.3
2002-2003	4	5.6	182	0.054	0.271	0.028	15.1	14.2
2001-2002	5	8.6	46	0.069	0.185	0.212	24.1	5.4
2000-2001	11.1	8.3	117	0.153	0.056	0.036	22.7	7.3
1999-2000	11.1	8.3	117	0.153	0.056	0.036	22.7	7.3
1998-1999	4.3	8.9	48	0.068	0.028	0.025	7.4	3.7
1997-1998	3.4	6.7	21	0.075	0.034	0.02	17.4	4.1
1993-1997	~	~	~	~	~	~	~	~
GL-P								
2003-2004	6	5.2	153	0.101	0.134	0.018	25.1	22.4
2002-2003	3	6.1	429	0.041	0.087	0.033	11.6	4.9
2001-2002	6	9.7	262	0.043	0.152	0.033	16.5	5.1
2000-2001	7.8	8.9	279	0.1	0.123	0.038	19.7	7.3
1999-2000	7.8	8.9	279	0.1	0.123	0.038	19.7	7.3
1998-1999	8	10.2	414	0.047	0.03	0.023	9.6	4.3
1997-1998	4.6	8	76	0.013	0.028	0.012	20.5	3.6
1993-1997	~	~	~	~	~	~	~	~

Table C.9 Smith Creek Water Quality Sampling Data

	Salinity (ppt)	Turbidity (ntu)	DO (mg/L)	Fecal coliform (CFU/ 100mL)	Nitrate (mg/L)	Ammonium (mg/L)	Phosphate (mg/L)	Chloro a (ug/L)	Total Suspended Solids (mg/L)
State Standard	0.5	Aquatic life = < 50 DWQ = < 25	Aquatic life = 5 Swamp = 4 DWQ = 5 to 14	200	DWQ = < 0.5	NA	DWQ = < 0.2	Aquatic life = 40 DWQ = < 30	NA
STATION									
SC-GT									
2003-2004	~	~	~	~	~	~	~	~	~
2002-2003	~	~	~	~	~	~	~	~	~
2001-2002	~	~	~	~	~	~	~	~	~
2000-2001	~	~	~	~	~	~	~	~	~
1999-2000	~	~	~	~	~	~	~	~	~
1998-1999	0.1	23.2	6.9	168	0.09	0.03	0.05	1	7.5
1997-1998	NA	27.4	NA	90	0.04	0.04	0.04	NA	21.6
1993-1997	~	~	~	~	~	~	~	~	~
SC-23									
2003-2004	~	~	~	~	~	~	~	~	~
2002-2003	1.3	18	6.1	224	0.124	0.125	0.078	8.5	13.1
2001-2002	0.5	18	6.7	93	0.102	0.07	0.042	19.2	14
2000-2001	0.5	16	6.5	122	0.095	0.033	0.053	10.7	13.2
1999-2000	0.5	16.6	6.4	196	0.056	0.052	0.038	4.3	11
1998-1999	0.9	23	6.1	124	0.1	0.07	0.05	6.3	11.5
1997-1998	NA	36.8	NA	58	0.19	0.05	0.06	NA	11.3
1993-1997	~	~	~	~	~	~	~	~	~
SC-CH									
2003-2004	2.3	19	5.9	104	0.117	0.096	0.025	4.5	20.1
2002-2003	2.9	24	6.3	144	0.159	0.1	0.053	6.5	24
2001-2002	1.8	19	6.9	89	0.212	0.087	0.067	12.8	20
2000-2001	1.8	18	6.7	104	0.149	0.029	0.063	5.6	16
1999-2000	1.5	17.1	6.8	116	0.143	0.048	0.058	1.8	13.4

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